AMERICAN MAMMALS

A Bighorn Ram

AMERICAN MAMMALS

Their Lives, Habits, and Economic Relations

BY

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McGRAW HILL BOOK COMPANY, INC
NEW YORK AND LONDON
1939

PREFACE

Our native mammals have received the attention of many competent authors. The resultant books have made available much information which long lay hidden and was largely unavailable to those most interested. Unfortunately, these volumes have dealt almost entirely with the mammals of a particular state or region or else have been prepared to serve as a guide to the habits and distribution of species inhabiting a larger area. Of the former, Lyon's "Mammals of Indiana," Warren's "Mammals of Colorado," and the "North American Faunas" of Bailey and A. H. Howell are especially fine. Anthony's "Field Book of North American Mammals" and Seton's "Lives of Game Animals" have filled a very pressing need.

Nevertheless, the author has long felt the need for a single volume which would include the characteristics and habits of North American mammals *in more* detail than has previously been accorded these subjects. Such a volume should presumably act as a reference text and be of more than passing interest to the layman, teacher, and professional zoologist alike. To be of the greatest value, the subject matter of such a volume should treat broadly of the entire field of mammalogy, with chapters devoted to reproduction, food getting, behavior, economic uses, and kindred discourses. Perhaps the nearest approach to this style has been Cabrera's admirable "Manual de Mastozoología" or Weber's "Die Säugetiere." Unfortunately, the former is difficult to obtain and "Die Säugetiere" is likewise rather inaccessible to the student of mammals. Moreover, in both volumes the emphasis on structure and habits is obviously not on North American forms.

The present volume is designed to fill this need It hardly seems necessary to add that a dozen volumes of this size would be required to treat the subject matter adequately It is hoped, however, that the inquisitive reader may find without long search within its covers the salient habits of our native mammals It may even prove an incentive for the young naturalist to commence field observations of his own

Let no one believe that the lives of our wild mammals have been completely catalogued Our larger game animals, because of economic considerations, are relatively well known, and this is in a measure true of certain rodents, whose habits have been studied only in enough detail to suggest proper control measures What do we know, other than in a very general way of the tiny shrew, billions of which are found over a greater part of North America? Where do the migrating bats, which flee the hostile northern winter, pass the months of snow and cold? When do the different species of bats have their fruitful mating? Is it in the fall, late winter, or early spring months? How do newborn moles appear, and how long do they remain in their subterranean nest? What do these nests look like and where are they placed? What is the home range of a black bear a raccoon, or a fox? Has man ever set eyes on the newborn of the bassarisk or of any one of a thousand different species on this continent? Who has spent long hours studying our common harbor seal so that he knows its ways? The burrow systems of our numberless ground squirrels have seldom been excavated How do these animals modify their subterranean dens in different environments? How do the skin glands of hoofed animals function? How rich the reward to one who would study the porpoise or dolphin schools of southern waters Indeed not a single species exists which would not repay some detailed study The more effort and time one directs to such a study, the more fruitful the results

The reader must not gather from this that no progress has been made in the study of field and systematic mammalogy Indeed since the latter part of the past century, when the

invention of the cyclone trap made it possible to capture large numbers of small mammals, the branch of science known as mammalogy has made great strides The advance in our knowledge of systematic mammalogy and distribution has been particularly gratifying Nevertheless, a promising field of investigation awaits those who are willing to spend long hours afield, collecting and observing in their natural haunts almost any species of North American mammals

For information relative to methods employed in securing and preparing specimens in the field, the reader is referred to Anderson's "Methods of Collecting and Preserving Vertebrate Animals," *Bulletin* 69 of the National Museum of Canada Equipped with this guide and a few dozen snap-back mouse traps, the veriest tyro cannot fail to catch a few species in any neglected field or wood lot

This volume includes all the mammal families of North America, from Panama to the Arctic Barrens Obviously, less is known of tropical mammals than of those of temperate zones, not because of any scarcity of species in the tropics but rather because fewer naturalists have studied there

The author has drawn freely upon any and all sources One of the most prolific of these has been the *Journal of Mammalogy*, which contains a veritable storehouse of facts relative to North American species Thanks are extended the New York Zoological Society, which has granted permission to use, in part, a paper of mine which appeared in its *Bulletin*

The drawings, except where noted, have all been made expressly for this volume by Lloyd Sandford under my supervision Many, if not most of these, have been made from live specimens at the New York Zoological Park or elsewhere A few have been prepared from alcoholic specimens in the Cornell University Museum

The author is grateful to Dr E Laurence Palmer for a critical reading of the entire manuscript

ITHACA, N Y
November, 1939

W J HAMILTON, JR

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CHAPTER I

THE ANCESTRY OF MAMMALS

THE principal environmental changes that have occupied the world during the past nearly half billion years and the parade of bizarre animals which have paralleled these changes provide an engrossing study Space does not permit detailing the changes during the Paleozoic era, but a brief account of Mesozoic life is necessary if we are to be prepared for the bewildering array of mammals that reached their culmination during mid Cenozoic times

Abundant testimony uncovered in the earth s rocks has provided scientists with a clue to the mode of mammalian descent Huxley believed the ancestry of mammals could be found among the Amphibia, although it is now generally believed that mammalian descent is traceable to reptilian stock This latter view was held by Cope and Owen, both of whom made outstanding contributions to our knowledge of archaic mammals, and it is the accepted view today The phylogenetic history of the very mammal like cynodonts and other therapsid reptiles is not complete, but it appears to be well established that these reptiles were the direct forerunners of the mammals

MESOZOIC LIFE

During the more than 100 million years of the Mesozoic, the climate and land masses of North America underwent profound changes, the more prominent of which must be

briefly reviewed to better picture the reasons for the dominance of reptiles and the beginnings of mammalian life

During the Triassic and Jurassic, Eastern North America underwent little change in outline, the land extending eastward several hundred miles into what is now the continental shelf Extensive epeiric seas invaded the site of the present western Cordilleras, and North America was broadly joined to Asia by an extensive land connection The great mountains of the Pacific Coast and the northern Rockies were rising An arid climate and seasonally cool conditions are thought to have existed Great forests of pines, cypresses and sequoias, cycads, which dominated all other plants, countless varieties of huge ferns, and giant horsetails were common The seas swarmed with immense dolphin like ichthyosaurs and long necked plesiosaurs while the swamps supported a varied reptilian stock Included among these were the huge dinosaurs some such as *Brontosaurus*

we find the continents again emerging and great mountains rising in western North America Glacial conditions existed in Colorado at the close of the Mesozoic, but elsewhere the climate was mild The flowering plants, in the form of fruits and grasses, were beginning to appear and undoubtedly played a significant role in the ascendance of mammals The rapid dispersal of angiosperms brought on great diversification among terrestrial animals Huge marine plesiosaurs and scaled mososaurs swarmed in the shallow seas Practically all the gigantic brutes which had followed diverse lines through the 140 million years of the Mesozoic were overspecialized

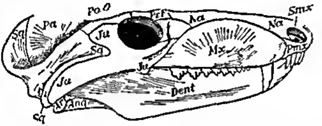

Fig 1—The skull of *Cynognathus platyceps* a mammal like reptile The reduction of the several bones of a reptilian mandible are here shown and foreshadows the single dentary bone of the mandible which mammals retain (*After Broom*)

but continued to thrive in the extensive inland seas and tropical marshes of the continent

Mammals were scarce, but with the decline of the mammoth reptiles which had so thoroughly dominated the world for millions of years, they tended to increase not only in numbers but in size During the Mesozoic however these archaic mammals were all of small size, scarcely larger than a chipmunk

THE RISE OF MODERN MAMMALS

It is to the Cenozoic or Modern era, estimated to have covered a span of 60 million years, that we must look for the rise of mammals Tremendous tracts of land, formerly occupied by extensive inland seas and wide marshes, were uplifted, mountains arose and what had once been a subtropical humid country was transformed into a land of plains and arid deserts

Migration was largely impossible because of the barriers imposed by the uplift The majority of reptiles, now hopelessly so overspecialized could scarcely readapt themselves to such radical changes in the environment Not able to overcome such an insurmountable obstacle, the majority of reptiles, including all the giants, faced extinction

Records of life from the transition of the Mesozoic to the Cenozoic are notably scarce and have left much room for theorizing Simpson[1] remarks on this dramatic change by stating

> It is as if the curtain were rung down suddenly on a stage where all the leading roles were taken by reptiles especially dinosaurs in great numbers and bewildering variety and rose again immediately to reveal the same setting but an entirely new cast a cast in which the dinosaurs do not appear at all other reptiles are mere supernumeraries and the leading parts are all played by mammals of sorts barely hinted at in the preceding acts

The progressive mammals of the lower Eocene were all immigrants, presumably of Asiatic origin, for these new comers appear in North America and Europe at approximately the same time. Extensive land connections between Alaska and Asia existed and formed a suitable passage for terrestrial species. How bizarre the indigenous giants must have appeared to the small immigrants! Perhaps the migrant most familiar to the reader was the little ancient horse (*Eohippus*) no larger than a house cat. The short neck, arched back, and slender limbs, with four functional toes on the fore foot and three on the hind, did not entirely disguise their equine appearance. The fossil record is so complete and abundant that it seems safe to infer that these pygmies abounded in the early Eocene forests. Small tapirs, scarcely larger than a collie and totally unlike those of the present, were common. Another small form, *Trigonolestes*, known only from imperfect remains, appears to represent the beginnings of the great ruminant tribe. Small monkey-like creatures peered from their arboreal retreat at the lumbering archaic amblypods, soon to disappear from the earth. The weasel-like forms and forerunners of the dog tribe are not yet known.

It should not be imagined that all archaic forms perished, or were displaced by more adaptable forms. Our common opossum is a striking example of a living prehistoric beast that was once contemporaneous with the giant reptiles. That it has changed little since the late Mesozoic is attested by finding skull fragments essentially the same as those of our present form. These fragments indicate a smaller animal which roamed parts of Canada 70 million years ago. This constancy is the more remarkable when we learn that striking changes can occur in a few million years. Some mammalian groups, originating as dog-sized species, attained the bulk of an elephant only to disappear completely, all in the course of 20 million years.

Eocene Mammals. Two great divisions of mammals occur in the early Eocene. One group, the archaic primitive forms,

were partly descended from ancestors of great antiquity in the Mesozoic, and most of them have left no modern descendants The others comprise mammals with modern descendants and relationships and were ancestors of living families The archaic mammals were a diversified lot, but were characterized by extremely small brains and the primitive five digits of hands and feet All were plantigrade

Appearing first in the Triassic and surviving into the lower Eocene, the multituberculates had the longest known history of any mammalian order, at least double that of the entire Age of Mammals These tiny and inconspicuous mammals,

FIG 2.—The skull of *Ptilodus* a multituberculate Multituberculates were among the earliest of mammals appearing in the Triassic and persisting into the Lower Eocene These small mammals were apparently rat like and, as their dentition suggests, were largely herbivorous (*From Romer, after Gidley*)

known only from imperfect skulls and teeth, are believed by various scientists to be the predecessors of either the monotremes, marsupials, or the early placentals They were characterized by the lack of canines and by the presence of a single pair of incisors which were rodent like in character The molariform teeth had many tubercles and were notable in other ways (Fig 2)

The Amblypoda were ancient hoofed animals, some of striking size These short-footed bizarre ungulates were among the most fantastic of this period *Uintatherium*, with its long narrow head adorned with bony protuberances, was elephantine in appearance and was among the largest of the Eocene terrestrial mammals Its small brain and inadequate

grinding teeth probably led to its downfall at the close of the Eocene. The Condylarthra were primitive ungulates, appearing, however, more like carnivores with their long tails and short dog like limbs. Some species reached the size of a tapir.

The Creodonta were an archaic assemblage of carnivores, still handicapped as were their contemporaries with low brain organization. To this group we must assign the ancestry of the carnivores, although the creodonts, unable to withstand

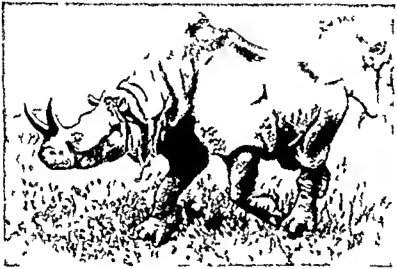

FIG 3.—The huge Brontotherium of the Oligocene had a brain scarcely larger than a man's fist. (After Miller and Gidley, Smithsonian Scientific Series.)

competition from a changing world, disappeared in the middle Oligocene in America. They did persist much longer than their archaic mammal confreres and are of major significance in the ancestral album of the Mammalia.

In the late Eocene, existing mammals developed greater size, particularly notable among the hoofed browsers. They were essentially mammals of the uplands and diversified enough to live in the trees, in the ground, in shallow seas, or above all, to lead a terrestrial existence on the earth's surface. Prominent among these was *Epihippus*, a small horse but slightly larger

than its diminutive forebear, already losing the splints of the hind foot and with the teeth foreshadowing those of a more advanced stage. Small, swift-footed rhinoceroses and diminutive tapirs abounded. The great cats had not made their appearance, nor were the true Carnivora present to any appreciable degree, although they were slowly usurping the waning creodonts. Archaic pocket gophers were present and appear to have changed little in their descent to the present.

Oligocene Mammals. Genial climates were characteristic of the Oligocene. Lands lay near sea level and North America was a great humid zone, at least near the sea. The prophetic Oligocene ushered in no end of new mammals, many of modernized type and distinctly recognizable as the predecessors of modern forms. During the middle and lower Oligocene, opossums, moles, and shrews were abundant. Many of these may have immigrated during the geologically short period when Europe was joined to North America by a land bridge.

Primitive carnivores were well represented and have supplanted the archaic creodonts. We find a diversified lot of dog- and cat-like animals which give promise of a varied fissiped fauna to come. In addition to these, small weasel-like mustelids have been recognized, bringing to the early Oligocene three families in sharp contrast to the numerous families

The upper Oligocene mammalian fauna was an indigenous one The families of carnivores were still limited, but the dogs and cats progressed and formed a wonderfully diversified fauna None were larger than a well-developed German shepherd dog, but undoubtedly in their variable assemblage were the ancestral stock of many present-day forms The cats, some approaching the cougar in size, were well represented and here we find the early sabre-tooths The hoofed animals were extraordinarily abundant, but the ascendancy of the artiodactyls over the perissodactyls had commenced The former were represented by the oreodonts, some of which were not unlike the wild boar in appearance and were as Scott believes the beginning of the proboscis bearing oreodonts, which attained such bizarre structure in the Miocene The most famous of the wild pigs were the giant entelodonts Many extinct genera of present-day rodent families flourished

Miocene Mammals The Miocene has been called the Mammalian Golden Age The prevailing cool and semi arid conditions wrought great changes in the vegetation endless grassy plains providing limitless food for the herbivores Adaptable groups responded to this change and became grazers, with profound modification of the cheek teeth resulting The browsers had low-crowned teeth that became rooted early in their development, the teeth were presumably adapted only for mastication of succulent leaves and twigs Those species with a plastic organization were undoubtedly able to mold their ways to this new environment of grass and as a consequence high-crowned cement-covered teeth resulted which continue to grow until advanced age Such cheek teeth were evolved to resist the abrasive nature of the grasses Other species, less adaptive, were not able to keep structural pace with the changing environment and were doomed

Throughout the Miocene, the fossil record yields abundant testimony that the hoofed animals were dominant and paraded over the prairies in amazing variety Three-toed horses abounded but a trend toward the unguligrade gait was ap-

parent, for in the late Miocene the lateral toes were much reduced. Such a condition is found in *Neohipparion* (Fig. 4) The weight is thus centered on the middle digit This, moreover, resulted in a lengthening of the leg, which again resulted in greater speed Speed became of paramount importance to these little horses, for the prairies abounded in fierce carni-

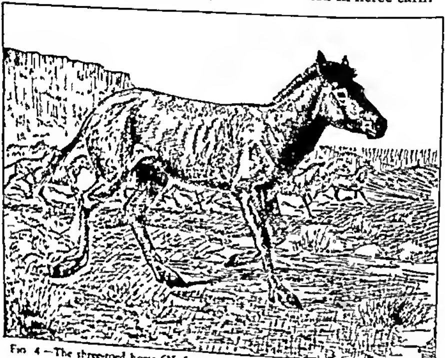

Fig 4 —The three-toed horse (*Neohipparion whitneyi*) roamed over the grass-studded prairies of South Dakota during the genial climates of the Upper Miocene

vores, ever on the alert for their equine prey. Rhinoceroses, both swift, long-legged ones and those more massive, were very abundant, less so were tapirs The chalicotheres of the lower Miocene were an aberrant perissodactyl group. This large horse-like creature in practically every respect, other than its feet, approximated its confreres. The digits, instead of bearing hoofs, were equipped with stout claws. The incongruity of the creature puzzled scientists for decades, and none first thought that skull and feet of this bizarre

creature could possibly have been from the same animal The relation to the horses and rhinoceroses can scarcely be questioned, but some would erect a separate order for these peculiar mammals

Of the artiodactyls, miniature camels (*Stenomylus*), scarcely larger than a deer fawn and totally unlike present-day species, roamed on the arid plains Grazing oreodonts were still common, while peccaries and giant boars (*Dinohyus*) as large as a bison rooted in the soil The tragulid (*Syndoceras*), characterized by grotesque horns on the face, suggests from its appearance possible ancestry of the deer and the giraffes, although this has not been demonstrated The deer were represented by a small hornless genus, *Blastomeryx*, probably ancestral to all American types of deer and *Merycodus*, possessed of branched antlers This deer was a tiny creature, not more than 20 inches high at the shoulder

Pliocene Mammals The Pliocene is a long epoch of cooling culminating in the marked glacial climates of the Pleistocene Some shores were bathed in increasingly colder currents, while the interior western plains experienced a more severe climate Pliocene mammalian remains are conspicuous only by their scarcity, the mammal life of the late Tertiary is still incompletely known Of the ruminants, several species of pronghorn antelopes abounded and some paradoxical creatures, having affinities with both the antelopes and deer, were not uncommon Deer were well represented most of them showing little similarity with recent forms *Cranioceras* from the lower Pliocene had three antlers These early deer were all characterized by small antlers with broad heavy pedicles, quite unlike those of existing genera Huge camels (*Colossocamelus*) towered 15 feet high, while their smaller llama like relatives were very numerous The camels were extraordinarily abundant during this period and quite probably rivaled the immense herds of bison and antelopes of historical times Of the nonruminants peccaries were common a prominent member of the Pliocene being very similar in size and appearance

to the collared peccary of today. Some genera attained the size of a wild boar but were not to reach their culmination and eventually disappear until the Pleistocene. The Perissodactyla were abundantly represented throughout North America. The long history of the horse was continued and we find *Pliohippus* a monodactyl genus, for each foot has but *a single hoof The slender legs are a feature of this horse,* while the character of the teeth, which continue to grow until old age, together with increasing size, lends an appearance

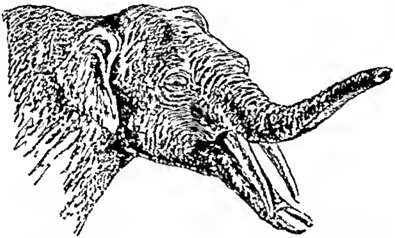

Fig 5.—The shovel tuskers (*Trilophodon productus*) apparently used their mandibular tusks to shovel in the soft mud of Miocene swamps The specimen shown was found in Donley County, Texas

which is not unlike that of our own ponies. The sturdy *Plesihippus* of the upper Pliocene had attained essentially all the characters of modern horses, except for minor differences which persist in the skull and teeth Rhinoceroses still abounded in the Lower Pliocene and were of a diverse order. some were heavy and short-limbed like the present African species, while others were built for greater speed and were possessed of relatively long limbs and a small trunk. The aberrant clawed chalicotheres have become scarce and probably disappeared in the early Pliocene

The Proboscidea had not yet become dominant in North America, but were represented by several long jawed mastodons, almost as large as the later mastodons These titanic beasts had long jaws provided with shovel shaped tusks, adapted to digging or uprooting plants *Trilophodon* (Fig 5) was almost as large as the mastodon

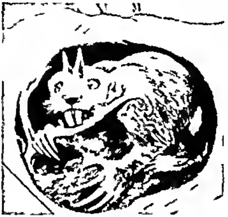

Fig 6—Restoration of *Epigaulus hatcheri* an extinct gopher like rodent (*After Miller and Gidley Smithsonian Scientific Series*)

Rodents were well represented and of modern character Many genera are represented in North America at the present, although few species persist One of the most bizarre lower Pliocene rodents was the horned gopher *Epigaulus* (Fig 6), which sported a pair of substantial straight horns in front of the eyes The Mylogaulidae were related to the present day primitive mountain beavers (*Aplodontia*) and were remarkable for their specialized teeth, a single tooth in each jaw being enormously enlarged and complicated at the expense of the others, which were much reduced One genus, indeed, had a horn developed on its nose

In this flourishing fauna of herbivores, one might naturally expect an equal development of the carnivores, and we find this to be true Great bear dogs (*Daphoenodon*), approaching wolves in size, with long massive tails, short powerful limbs and digitigrade feet, undoubtedly were successful in striking down the little horses, but their teeth indicate an omnivorous diet Some of these bear dogs, so called because of their affinities with the bears, approached their ursine cousins in size The terrible sabre toothed cats had made their appearance but none were large Even at this early age we find,

among mustelids, the weasels, wolverines, and skunks becoming separated from their ancestral stock.

Edentates were among the dominant mammals of Neotropical America from the Miocene through the Pleistocene, but though the nine banded armadillo alone survives in the United States today, the xenarthrous edentates were well represented as far north as Canada, where they spread during the Pliocene. The huge ground sloths which are associated with the Pleistocene had scarcely made their appearance in North America in early Pliocene times, but the huge armored glyptodonts ranged throughout southern United States, reaching their most bizarre development in South America, however, where these giant armadillo like creatures attained a length of 12 feet and stood shoulder high to a man.

Pleistocene Mammals The geologically brief Pleistocene was a critical period for all life of the glaciated lands. Successive ice sheets mantled most of North America as far south as the vicinity of New York, Cincinnati, St Louis, through Omaha, thence north to a line several hundred miles south of, and roughly paralleling, the international boundary. Great ice caps covered the higher peaks of the Rockies and Sierras. These enormous ice sheets are thought to have been a mile thick in places. Evidence points to successive glaciation, alternating with warm stages, in which such southern species as the imperial mammoth, peccary, and tapir invaded the regions once capped by these ice sheets. As the ice again blanketed the continent many polar forms retreated before it. Mute evidence of this may be found in the musk-ox remains of Indiana and the many finds of the extinct woolly mammoth, some as far south as Arkansas.

The Pleistocene fauna of North America was notable for its great wealth of huge mammals. Continual immigration from South America and Asia swelled the already rich indigenous fauna, so that the varied mammal life would indeed have excited a museum collector could he head an expedition into this strange living world. Of all the inhabitants of the Pleis

tocene plains and forests, perhaps the most striking were the mammoths, the variable antelopes, many species of horses, great fanged cats, and immense ground sloths Most of these are extinct but constitute representatives of North American genera now living

The Pleistocene Proboscidea were the most striking animals of North America Their history is quite well known Not only have entire skeletons been preserved and even the flesh of animals recovered from the frozen gravel of the tundra, but realistic and spirited drawings of Paleolithic artists give a clue to their seasonal appearance Originating in Africa, they became widely distributed throughout Europe, Asia, and North America by the Pleistocene The mastodons and mammoths, while appearing superficially alike, differed structurally, notably in the cheek teeth *All* recent proboscideans have only a single pair of anterior teeth, the prominent tusks, which attain enormous proportions The masrodons possess low-crowned cheek teeth not unlike those of pigs, and, as with other mammals, many or all of the cheek teeth are in place simultaneously On the other hand, the cheek teeth of mammoths (and present-day elephants) are remarkable, meeting the requirement

of a large grinding surface in a unique manner. Half of each jaw possesses three milk premolars and three molars, all of which are very complex (Fig. 7). The compressed elongate teeth have a surface of numerous crosswise ridges, between which is cement. The dentition is different from that of the mammoth in an even more striking manner; only one tooth

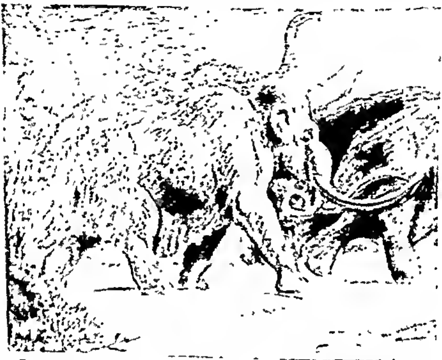

FIG. 8.—The woolly mammoth of the Pleistocene. The huge pads on the shoulders and head are thought to have been fat reservoirs which the animals utilized during the bleak glacial periods

in each side of the jaw is exposed at a time, and as these are worn down they are replaced by one which has been forming in the maxillary or dentary. Moreover, the teeth push into the tooth row at an angle, allowing for an uneven wear. Thus an exposed tooth shows the surface wearing diagonally.

The mammoths were all immigrants from Asia, coming into America by way of the broad Alaskan-Siberian land

bridge which in Pleistocene times joined the two continents Perhaps the best known of the three was the woolly mammoth (*Mammonteus primigenius*), an animal which frequented the edge of the great ice sheets (Fig 8) In appearance this superb beast was quite dissimilar from the elephant as we know it today The entire body was thickly covered with fine soft hair, over this a heavier coat, in places 20 inches long, protected the mammoth from the fierce arctic storms The great bulbous forehead and thick layer of fat all over the back served as a reservoir upon which to draw during the long bleak arctic winter The tusks of all mammoths, unlike those of the African elephant, spread apart and slowly rotated on their axis, in advanced age, the tips actually crossed to form a huge ivory circle The tusks are not thought to have been used for digging or uprooting purposes, but chiefly for defense of the young from their enemies The extreme specialization of the teeth is an adaptation to a grassy diet, in contrast to the contemporaneous browsing mastodon, which likewise was a forest dweller but ranged as far south as Florida The mammoth was as important to European men of the Old Stone Age as cattle to our generation The ivory, superior to bone for many purposes, was used for realistic etchings and tools, and the flesh was apparently prized for food At any rate, the great beasts were trapped in pitfalls and destroyed by huge rocks toppled on their heads In North America the woolly mammoth ranged from Alaska through Northern United States To the south it was replaced by *Paraelephas* These mammoths were probably hairy, but only to a slight degree and then only during the winter season They ranged through middle United States south into Mexico Finally, *Archidiskodon*, the imperial mammoth, stood fully 13 feet at the shoulder, thus towering over the largest African elephant It was probably hairless and possessed of great encircling tusks One of these tusks unearthed in Texas measured 15 feet 4 inches and had a circumference of 25 inches Remains have been found in Southeastern United States and Central America

Artiodactyls were much better represented in the Pleistocene than today. Several species of bison roamed the prairies and extended into the forested regions of North America as well. The most spectacular of these was the gigantic *Bison latifrons*, whose great horns had a spread of 6 feet (Fig 9). Relatives of the musk-ox, but with horns fashioned after a

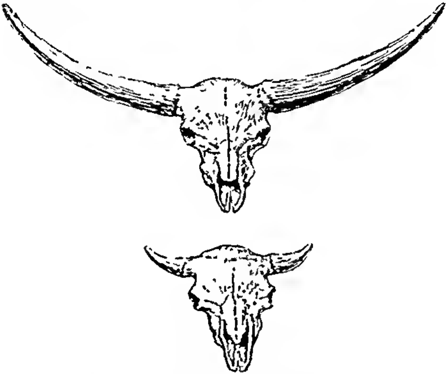

Fig 9—The Pleistocene bison (*Bison latifrons*) contrasted with the Plains bison (*Bison bison*) The former had a horn spread of six feet

Texas longhorn, have been obtained from California caves The pronghorn (*Antilocapra*), swarmed on the plains with four-horned contemporaries, some of which were less than 2 feet high at the shoulder. The huge moose-like *Megaceros* and many bizarre deer, long extinct, flourished into the late Pleistocene Camels (*Camelops*), llama-like in appearance but towering over man at shoulder height, persisted into the late

Pleistocene, these grotesque abundant beasts are thought to be contemporaneous with man 20,000 years ago Wild pigs frequented the entire country, many being considerably larger than the peccaries of Texas today

Of the Perissodactyla, the horses (*Equus*) were in all probability the most dominant of hoofed animals Disparity in size was great, some species scarcely attaining the size of a great dane, while others approached the largest percheron stallion in height and massiveness and were, in appearance, not unlike those of recent times Tapirs similar to the existing species of the American tropics occurred in the forests of Eastern United States

The Pleistocene rodents did not differ essentially from those of today Many species, indeed, have probably undergone little change in the past million years It is certain that the genera of today were represented in the Pleistocene The fossil remains of Pleistocene rodents are notable for their paucity, as are all small species The giants of the tribe must be mentioned, for it is these that excite the greatest interest The capybara (*Hydrochoerus*) the largest living rodent, is now restricted to South America, but in the Pleistocene inhabited southern United States (Fig 47) Of greatest interest was the giant beaver (*Castoroides*) remains of which have been found in several widely separated northern states, indicating its extensive range This tremendous rodent was more than 7 feet long and as large as a small black bear

The smaller carnivores were essentially as they are today, but many extinct forms were veritable giants compared with present-day species The huge sabre-tooth tiger with its formidable scimitar like tusks is familiar to every school child The great canines were not used as biting instruments for the impossibility of this is indicated by their position (Fig 10), on the contrary, they were used as effective stabbing organs On this score, Scott[2] says

> So far as the Pleistocene and Pliocene genera are concerned it is not necessary to suppose that the lower jaw was so far dropped in an attack as to

FIG. 10.—The terrible tusks of the sabre-tooth tiger (*Smilodon*) were used as stabbing weapons. Unlike our mountain lion of today, these Pleistocene cats had tremendous fore limbs and shoulders. The tail was short.

clear the points of the tusks, for, when the mouth was closed the canines projected several inches below the lower jaw, enough to inflict frightful wounds though, no doubt, open mouthed blows were also struck This conclusion, at first sight, seems incredible, yet it is the one at which all students of the problem have arrived

There are many other anatomical details, such as the great neck muscles, the weak chin, and the small lower jaw, which lend support to this stabbing hypothesis The fore limbs were tremendously developed and this had much to do with their habits and manner of securing prey Scott believes that the smilodont cats were not swift runners, but resorted rather to their tremendous strength These cats have been pictured as lying in wait at a water hole, or elsewhere in ambush, striking down their victim in one grand leap, clubbing it to the ground with the huge forepaws and soon killing it with vicious stabs from the curved sabres

Foxes, wolves, and coyotes of the Pleistocene had much the same appearance as they do today, but the extinct dire wolf (*Canis dirus*), a heavy headed dog, towering over the largest timber wolf, was cootemporaneous with the sabre-toothed cats

Not the least interesting of Pleistocene mammals were the American edentates The Xenarthra invaded North America from the Neotropical region during the Pliocene and Pleistocene, and we find some mammoth individuals among these Plaster casts of *Megatherium*, as large as an elephant, exist in every important museum and depict these huge ground sloths feeding on the herbage of trees *Megalonyx*, another colossal ground sloth, rests its chief claim to fame on its discoverer, Thomas Jefferson, who described it in 1797 and, as Scott puts it, founded the beginning of American vertebrate paleontology The glyptodonts, armadillo like but with a turtle like covering fused into a mass of countless small plates, were larger than a big pig and ranged widely throughout Southern United States Remains have been recently uncovered in Florida

EXTINCTION OF ANIMALS

While a few primitive mammals have maintained their place in the world for many millions of years, others have ascended to prominence, only to be pushed into final oblivion by one or several forces The prominent age of reptiles, which drew swiftly to a close as the Mesozoic era waned, implied that races or families disappear with apparent abruptness Such is largely illusory, and may be attributed only to the paucity of records which would otherwise show a more gradual decline Moreover, these extinctions were not cataclysmic in nature, but started from local centers and worked over the entire range of the species The discontinuous distribution of many present day forms, such as the tapirs, opossums, rhinoceroses, and elephants, are mute reminders of former widespread families, indicating very plainly, as the fossil record will substantiate, that these animals have failed to survive over their once extensive range

Probably the major changes in the environment during the history of life have occasioned the extinction of more species than any other cause With the elevation or subsidence of land masses, changes occur in moisture, temperature, and a number of other climatic factors Only a slight elevation of land masses would permit emigration of competitors over bridges thus formed

The gradual change of climate resulting in an altered physical environment, undoubtedly hastened the decline of many species With the secular lowering of temperature over many thousands of years the mammoth, woolly rhinoceros camel, and musk ox were able to develop a suitable covering which provided immunity against the frigid climate of the Pleistocene Others, less adaptable, disappeared

Darwin suggested that temporary diminution in the population of a race, through cold waves, drought, flood, epidemics, and other causes, may result directly in extinction

When the numbers of any species are so reduced that they can no longer effectively protect their young or find suitably synchronized mates, ultimate extinction results. The caribou herd of northern Minnesota, reduced to a few dozen animals, could no longer protect themselves against the attacks of wolves and were eventually reduced to three animals. The herd has been enlarged by the addition of Canadian individuals, but there seems little likelihood of again establishing these animals in the United States.

Lowering of temperature may result in a diminished fertility and thus bring on extinction. Osborn[3] believes that the barriers to reproduction imposed by low temperature may have repeatedly been a cause of extinction in the earth's history, that certain mammals may have resisted exposure to cold or discovered new forms of food and yet suffered extinction through the subtle inhibition of fertility and reproduction.

Dust storms undoubtedly took toll of entire areas, often of extensive size. We know that the current cycle of dust storms in the Dust Bowl has been responsible for the death, through choking and thirst, of much livestock. There is evidence that the Pleistocene storms were many times as severe as these. Thick layers of dust over prehistoric victims suggest that such storms upon occasion were responsible for death.

Nowhere in the world are conditions so favorable for the maintenance of the hoofed animals as the plains of Africa, where moderate rainfall and arid summers are the rule. If, then, a long period of wet years follow one upon another, the hardier grasses, which ungulates favor, diminish and in their place plants less suited or even deleterious to these animals may develop. Osborn believes that the periods of secular increasing moisture such as the early Pleistocene of the Northern Hemisphere is supposed to have been, may have been most unfavorable to certain large quadrupeds. He further indicates that secular desiccation has been the fate of portions of three

great continents and on each continent there has been a general concomitant modification and extinction of certain kinds of quadrupeds

Disease, transmitted chiefly by insect vectors, must surely have been a prominent agency in depleting great areas of their natural fauna in past ages The almost total absence of hoofed animals in parts of South America where the navel worm exists is a mute reminder of restriction of territory imposed by pests By constant mechanical irritation, insects have prevented the extension of range by many large mammals, and the resultant crowding in a restricted territory might conceivably be penalized by partial extinction

Competition between existing groups often spells disaster to the less adaptable The creodonts once flourished over much of the Northern Hemisphere, but with the rise of true carnivores the creodonts perished Although hostile aggression by predators may not have been a direct cause of extermination, it probably acted at some time to destroy an unadaptable and diminished race which could not withstand adverse conditions of the physical environment or other factors which had weakened its prey It is barely possible that the early mammals, scarcely larger than rats, fed on the eggs of the contemporaneous reptile giants and so hastened the decline of these formidable beasts

It seems obvious, however, that no one factor has been responsible for the decline and ultimate extinction of any one race The cumulative effect of numerous factors invariably causes the final disappearance of a species from this world

BIBLIOGRAPHY

1) Simpson, George Gaylord 1937 *Biol Rev* 12 2.
2) Scott William B, 1937 A History of Land Mammals in the Western Hemisphere New York, pp 605-606
3) Osborn Henry Fairfield 1906 *Amer Naturalist*, 40 779-780

CHAPTER II

CLASSIFICATION

SYSTEMATIC mammalogy, or the phase of this science which is concerned with desctibing and placing in their proper order new forms, has occupied the attention of naturalists fot a long time. Linnaeus was able to list only 86 species of living mammals in 1758.[1] Improved methods of collecting and explotation resulted in increasing numbers being recognized by science. In 1898 Trouessart recognized 4,423 living forms.[2] By the beginning of 1925, 8,117 living species and subspecies from all over the world had been added to those previously known, btinging the total number of forms to 12,540. Poole[3] finds that at the close of 1934 there were a total of 14,464 known species and subspecies of mammals, a number which probably is not far from the correct summary of the forms of living mammals recognized at that time.

New species are constantly being added to the list of recognized forms, at the rate of several hundred every year. Miller[4] believes that when the count is completed and all species and their varieties are described, the total number will possibly be found to exceed 20,000.

To classify properly this great number is a tremendous task. Vernacular names would be quite insufficient; descriptive terms for even the commoner forms would soon be exhausted The method which is employed to designate each new species is one outlined by the famous Linnaeus.

Mammals are classified according to blood relationship, but it is not always an easy matter to tell what constitutes

such ties Species have been moved from one genus to another, lumped or split into minor groups, until their relationships appear fairly well established

The various mammalian orders are based on major differences characteristic of a group These are differences of major significance, such as the presence or absence of canine teeth, the number and character of the incisor teeth, modification of the fore limb into a flying membrane, flippers or complete loss of such limbs, modification of the digits, presence of claws or hoofs, the structure and complexity of the brain, and such other major characteristics as are common to the entire group

Family characters are determined by structures of a less important nature, features which are often associated with the internal modification of the animal The character of the teeth, particularly the molars, the presence or absence of skull structures, the general modifications of the external body form to meet environmental conditions which often differ markedly, all contribute to the appearance of the animal which set it off as a distinct family

Generic modifications are less marked and have to do with tooth and skull characters, but external features are often well marked and frequently differentiate the animal from even a closely related genus Such is not always the case, for the little lemming mouse (*Phenacomys*) of Ontario can scarcely be distinguished from the field mouse, an examination of the teeth being necessary to distinguish the two (*Phenacomys* possesses rooted molars as contrasted to unrooted molars in *Microtus*) External generic differences may be well marked, as we can readily observe among the squirrel tribe Witness the long-tailed graceful tree squirrels and the short heavy-set ground squirrels and woodchucks All belong to the Sciuridae, but major differences in habit and habitat have made for rather decided changes which stamp them generically dissimilar

Specific differences are chiefly those of size, color, distribution of markings, and other prominent external characters

Variation in skull structures associated with different species are usually minute, seldom having to do with differences in tooth number It is difficult to recognize specific differences in fossil mammals, for individuals may vary sufficiently to justify a separate binomial name for each, and this would be utterly impracticable There are about 10,000 different fossil mammals now known to science, and all are recognized from skeletal material only Specific differences having been lost, it is thus impossible to assign a name to each new form to be described

The recognition of specific differences is a matter of a personal equation What one systematist might consider a valid species might not be considered such by another describer Moreover, the assigning of generic rank to an animal by one scientist might not accord with the views of another, who would consider the animal in question only a species of an existing genus This difficulty arises from the lack of a definite criterion by which animals can be grouped into species or genera The so-called lumpers are not concerned with minute differences, which they feel may be explained on the grounds of individual variation Splitters seek minutiae which will differentiate existing forms into species or subspecies

While morphology has been the tool of mammal taxonomists, the writer believes a physiological approach might conceivably be of equal value in determining the relationships of species While blood relationships have been studied through precipitation tests, such inherently useful factors as gestation length might also be appraised to fathom true relationships Habits likewise appear of value in this matter Unfortunately, these are not tools with which the systematist may conveniently work, and this intangible nature largely precludes the possibility of using such in a classification of living forms

In the following discussion, the chief characters of the orders families, and genera are given Lack of space obviously excludes treatment of all the genera, only a few of the repre

sentative ones are mentioned Many of the tropical genera discussed range into South America, where the range is said to extend south to Panama (the scope of this book) the reader should understand that this does not imply that the genus under consideration does not occur in South America

CLASS MAMMALIA

ORDER MARSUPIALIA

The marsupials are the most primitive of American mammals They are characterized by the simple form of the brain, the presence of epipubic bones on the pelvis, and the unique angular process of the jaw, which turns inwards The entire order is further remarkable for the peculiar reproductive tract of the female, in which the uterus and vagina are double, although coalescing into a single external opening No placenta is developed to nourish the embryo, which is born in an extremely undeveloped state (Fig 56) The order is best represented in Australia, where a great diversity of forms occurs, illustrating well how families within an order may appear remarkably dissimilar externally to meet the various conditions under which they live A few marsupials are found in South and Central America, only the one but well known genus *Didelphis* extending into the United States

Family Didelphiidae (Opossums)

Representatives of this family are of medium to small size The teeth number 50, the incisors being small and pointed and the last premolar preceded by a deciduous multicuspidate milk molar The limbs are moderate, each having five distinct toes, the hallux being opposable and without a nail The pouch is generally absent, when present it is often represented by two lateral folds which partially cover the teats The family is represented in North America from New England to Panama

Didelphis is about the size of a house cat, having naked ears and a long prehensile tail The female of the Virginia opossum has a well developed pouch or marsupium in which the young

FIG 11 —The opossum has an *omnivorous dentition* for it feeds on fruit berries insects and flesh These primitive beasts have an unusually small brain case

remain until they are about two months old The teeth number 50, a large number for a heterodont condition (Fig 11) The first toe of the hind foot is clawless and opposable lending a peculiarly human like track which can scarcely be mistaken The opossums range from Panama to Vermont and Michigan, where they are rapidly extending their range northward The mouse opossum (*Marmosa*) is scarcely larger than a small rat, the female is without a pouch, and the animal has an extraordinarily long tail (Fig 12) Murine opossums occur from Mexico to Panama Woolly opossums (*Philander*) are found from Mexico southward

FIG 12 —A murine opossum (*Marmosa isthmica*) These little tropical marsupials often come to the United States as stowaways in bunches of bananas

The water opossum (*Chironectes*) is somewhat smaller than our Virginia opossum, is strikingly marked, and is remarkable for being the only marsupial which is even partially aquatic Its webbed hind feet suit it for existence in the Panamanian streams which it haunts

ORDER INSECTIVORA

The insectivores are mostly small animals, none exceeding a small cat in size. These placentals have a primitive brain, the cerebral hemispheres of which are smooth. The teeth are primitive, with well-defined cusps, and the canines, while always present, are simple and shaped like the near-by incisors. The snout is usually long and tapering, extending well beyond the end of the skull. The order is found throughout nearly the entire world, but none occurs in Australia nor are they well represented in South America.

Family Solenodontidae

These are America's largest insectivores, exceeding a gray squirrel in body size, with long coarse fur and a long naked

FIG 13.—*Solenodon paradoxus*, a large insectivore of Santo Domingo. The Cuban *S. cubanus* is probably extinct.

tail (Fig. 13). The skull has a small brain case much constricted between the orbits, while the zygomatic arch and auditory bulla are absent. The teeth are reduced to 40. *Solenodon paradoxus* occurs in Haiti, while *S. cubanus* is found only in the mountains of Oriente, Cuba.

Family Talpidae (Moles)

Moles have a long narrow skull, a slender but complete zygomatic arch, and a tremendous development of the shoulder girdle (Fig. 40). There is an apparent absence of the neck. The fore feet are extremely enlarged, the eye is minute, and the external ear is absent; the animal is admirably adapted

for a subterranean existence American moles range from Quebec, Minnesota and southern British Columbia south to Florida, Texas, and Lower California, but are absent from the desert country

The common mole (*Scalopus*) has a short naked tail pale velvety fur, and 36 teeth It occurs throughout Eastern North America west to Nebraska and south into Florida and Mexico The star nosed mole (*Condylura*) has a long tail, a wide nasal disk of fleshy processes, and 44 teeth It is an inhabitant of Northeastern America The little Gibbs mole (*Neurotrichus*) has an annulated and hairy tail but the fore feet lack the extreme development of other moles It occurs in the humid regions from British Columbia to northern California

Family Soricidae (Shrews)

All shrews are small mouse like mammals, with soft fur, sharply pointed muzzle, and minute eyes The skull is long

Fig 14—A long tailed shrew (*Sorex*) Shrews are characterized by small size minute eyes and a *long pointed snout* They belong to an archaic family which has a world wide distribution

and narrow, strongly tapering anteriorly, the zygomatic almost wanting and the mandible with complete double articulation The anterior teeth are not differentiated by form into incisors canines and premolars The first upper incisor is very large projecting forward strongly Shrews occur throughout all North America except in the desert country, and extend into the extreme northern part of South America

The genus *Sorex* are small shrews with a long tail (Fig 14) and 32 teeth They occur well within the Arctic Circle south to Mexico *Microsorex* is the smallest of American mammals

It is distinguished from the preceding genus by its much smaller size, scarcely exceeding 3 inches in total length The third unicuspid is disk like flattened anteroposteriorly These diminutive shrews seldom equal a ten-cent piece in weight Pygmy shrews are distributed from Northern North America south to Virginia The short tailed shrews (*Blarina*) are large, with inch long tails They occur in the eastern half of United States and adjoining Canadian provinces west to Nebraska

ORDER CHIROPTERA

All bats possess fore limbs that are modified for true flight, the fingers being greatly elongated and joined together by a membrane which extends to the sides of the body and legs The knee is directed backward owing to the rotation of the hind limb outwards by the wing membrane The shoulder girdle is much better developed than the pelvis and the sternum is usually keeled Bats are chiefly crepuscular or nocturnal They feed largely upon insects, although some tropical bats are frugivorous, piscivorous, or carnivorous Because of their power of locomotion the order is widely distributed including all of North America

Family Emballonuridae (Sac winged Bats)

In these tropical bats the tail perforates the interfemoral membrane and appears on its upper surface, or is produced considerably beyond this abbreviated membrane Genera of this family range from Mexico to Panama The spectral *Diclidurus* is remarkable for its white fur a most unusual color for any tropical mammal It is found in Costa Rica and in Panama

Family Noctilionidae

The fish-eating bats have large first upper incisors close together, concealing the small outer ones there is only a

single pair of small incisors in the lower jaw This anomalous dentition led Linnaeus to remove the species from the bats and place it with the rodents *Noctilio* has erect cutaneous processes on the chin (Fig 15) and enormous feet and claws These bats occur from Mexico and the West Indies south into northern South America

Fig 15 —Many bats of tropical North America have nose leaves and cutaneous facial excrescences The specimen figured is a spear nosed bat (*Phyllostomus*) of Panama

Family Phyllostomidae (American Leaf nosed Bats)

Leaf nosed bats are best characterized by the prominent cutaneous nasal outgrowth, which is often well developed The premaxillae are particularly well developed, as are the molar teeth This heterogeneous family includes more species than any other tropical group While the largest of American bats are placed here, others of the family are characterized by their small size No less than six subfamilies are recognized In some members of the family the external tail is lacking, while others possess a prominent one Leaf nosed bats occur in California, Texas, Mexico, and range to Panama and the West Indies More than 40 genera occur from Panama northward

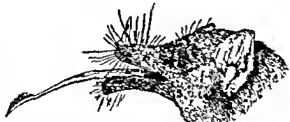

Fig 16 —The fruit-eating bat (*Choeronycteris mexicana*) has a long tongue admirably adapted for feeding on pulpy fruits (*After Dobson*)

Macrotus is of medium size, with a prominent nose leaf and large papery ears which are connected across the forehead. It is represented by various species in California, Mexico, Central America, and the West Indies. The spear-nosed bat (*Phyllostomus*) feeds upon other bats, mice, and small birds. The false vampire bat (*Vampyrus*) is the largest of American bats, having a wingspread of 2½ feet. The name is a misnomer, for the bat is known to be quite harmless, but its physiognomy is hideous. The long-tongued bat (*Choeronycteris*; Fig. 16) is admirably adapted to lick away the juice and pulp of soft tropical fruits.

Family Desmodontidae (Vampire Bats)

Vampire bats are true blood suckers and are well equipped for blood sucking by the formidable dentition. These small bats are tailless and are otherwise distinguished by the intestiform shape of the stomach. Vampires range from Mexico to Panama but appear to reach their greatest number in Northern South America.

Family Natalidae

These small delicately formed bats have distinct funnel-shaped ears, slender legs which are noticeably elongate, and a very large tail membrane. Nose leaves are absent. Representatives may be found from the warmer parts of America north to the Bahama Islands and central Mexico.

Family Thyropteridae (Disk-winged Bats)

The members of this family are immediately distinguished from all other bats by the presence of a large sucking disk on the thumb and a smaller one on the sole. The bats occur from Honduras to Ecuador.

Family Vespertilionidae

The small bats of northern latitudes of both hemispheres are included in this large family. The individuals of the

family are usually characterized by small size, simple muzzles and lips, and separate ears with well-developed, straight, or slightly curved tragi The tails are long and extend to the edge of the interfemoral membrane The ulna is fused to the radius at its head, the shaft being reduced to a mere ossified fibrous strand This family is regarded as among the highest of the bats, largely because of its wing structure It stands

Fig 17—A little brown bat (*Myotis lucifugus*) in flight The extended tragus of the ear curved tail membrane thumbs and other structures all show well in this remarkable picture of a flying bat (*Photograph by Prof H E Edgerton*)

farther removed from non volant mammals than any other family These bats are cosmopolitan, extending in North America to the limit of tree growth and south to Panama and the West Indies (Fig 17)

Myotis, a small, delicately molded bat, is represented by many species in the United States It has a slender ear with a prominent tragus The tree bats (*Lasiurus*) have a short deep skull, well furred interfemoral membrane, and a short rounded ear The genus occurs over entire North America to the limit of tree growth and south to the Greater Antilles One of the

most striking species of temperate North America is the big-eared bat (*Corynorhinus*) with its huge ears (Fig 45)

Family Molossidae (Free-tailed Bats, Mastiff Bats)

This family includes bats of variable size, but all are prominent for their streamlined appearance and swift flight The hair is short and satiny, the short, thick leathery ears projecting forward over the face The tail extends conspicuously beyond the interfemoral membrane, thus giving rise to the name free tailed bats These bats extend from Southern and Western United States south into Panama and the West Indies *Tadarida* is one of the commonest bats of the Southwest and Mexico, millions literally roosting in the great Carlshad Cavern of New Mexico

ORDER CARNIVORA

The carnivores, or flesh eaters, are terrestrial (rarely aquatic) placental mammals with a well-convoluted brain, the cerebral hemispheres having distinct fissures The detention is adapted for a flesh diet, one tooth in each jaw being specially modified (the sectorial or carnassial tooth) and taking the form of a compressed blade having two or three roots The incisots are small, but the canines usually project well beyond the other teeth and are well adapted for seizing prey The alimentary canal is simple in structure The members of this order vary greatly in size, from the tiny least weasel scarcely larger than a chipmunk to the huge Alaskan bears weighing more than half a ton The order is widely distributed and is found in all continents except Antarctica, Australia, and New Zealand where there are no endemic forms Six families occur in North America

Family Ursidae (Bears)

All our native bears are characterized by large size, rudimentary tail and plantigrade feet The teeth are not so trenchant as in other carnivores but have rather blunt crowns

(Fig 29), and the carnassial tooth is smaller than the rear molars The teeth are 42 in number Bears are found throughout North America wherever suitable habitat occurs

The black bears (*Euarctos*) are smaller than their American relatives, although the Florida species weighs more than 500 pounds A straight facial profile, short front claws which are scarcely longer than the hind ones, and the black or cinnamon color characterize the genus Black bears are found throughout forested North America wherever there are suitable conditions for their existence The grizzlies and big brown bears (*Ursus*) are the largest of North American carnivores, indeed the Kodiak bear (*Ursus middendorffi*, Fig 83) is probably the largest terrestrial flesh eater in the world Members of this genus may be at once recognized by the concave facial region, the long and slightly curved claws, and the light brown or yellowish brown hair, often tipped with silver They are found in the Rocky Mountain region north to Alaska The polar bear (*Thalarctos*) is a small-headed, long necked white bear which inhabits arctic America

Family Procyonidae (Raccoons, Coatis)

This family consists of medium to small-sized carnivores with plantigrade or semi-plantigrade feet, all of which have five toes The tail is long, bushy, and often ringed and prehensile The carnassial teeth are not typically developed, while the molars are broad and tuberculate Representatives of the family occur from Canada to South America

The raccoon (*Procyon*) has a stout head and body, the former with a distinct black mask Its bushy tail has alternate black and yellowish rings There are 40 teeth Raccoons occur throughout most of North America from 50° latitude southward Coatis (*Nasua*) have a somewhat elongate but compressed body, undoubtedly an adaptation for their arboreal habits The nose is prolonged into a somewhat upturned, obliquely truncated mobile snout The long tapering annulated tail is partly prehensile Coatis occur throughout

Mexico and Central America The kinkajous (*Potos*) are distinguished by their short faces and ears, small rounded head, and the long, round, tapering, short haired prehensile tail They are found from Mexico to Panama

Family Bassariscidae (Cacomistles)

This family is somewhat similar to the Procyonidae, but the dentition differs, the incisors have small secondary lobes, the canines are rounded, and the cheek teeth are rather dog like with sharp cutting cusps The feet are similar to those of a cat, the digits being fully webbed or nearly so The beautiful tail is very long, with alternating annulations of dark and white fur Ringtailed cats occur from Oregon and Texas south to Panama

Family Mustelidae (Weasels, Skunks, Otters, Etc)

The weasel tribe is a variable one, ranging from medium size (sea otter) to diminutive (least weasel) beasts The body may be elongate, squat, or broad The legs are usually short and are digitigrade, plantigrade, or semi plantigrade, there being five digits to each foot The various genera are terrestrial, arboreal, semi aquatic, or wholly aquatic The skull has a short rostrum and a large depressed brain case The anal scent glands are usually prominent Of the 18 genera 11 are found in North America, ranging from north of the Arctic Circle to Panama

The weasels (*Mustela*) have long slender bodies and short legs with digitigrade feet The tail is long and usually tipped with black Pelage is short but dense and there is usually a prominent anal scent gland The striped skunks (*Mephitis*) are robust terrestrial animals with short legs and very bushy long tails The color pattern is conspicuously black and white, while the anal scent glands are highly developed (Fig 90)

The badgers (*Taxidea*) are heavy squat animals, with a short tail and long grizzly gray pelage The face is conspicuously marked with black and white The fore claws and limbs are

well developed for digging. Badgers are found throughout Central and Western North America from Saskatchewan to Mexico. The sea otter (*Enhydra*) is admirably built for a marine existence. The supple body is densely clothed in thick fur and the hind feet are seal like, being broadly webbed and haired on both surfaces. The animals are nearly 4 feet long. They occur from Bering Sea to Lower California.

Family Canidae (Wolves, Coyotes, and Foxes)

The dog like Canidae are medium sized, with elongate muzzle and long legs. The feet are digitigrade, there being four toes on the hind feet and five on the fore feet, the claws are non-retractile. The pelage is normally long and thick, producing a good commercial fur, and the tail is bushy. The teeth are highly developed for a shear like crushing function with a well-developed sectorial tooth. There are 42 teeth in all American species. A prominent gland is located on the dorsal surface of the tail base. The family is widely distributed throughout North America.

Fig. 18.—Timber wolf.

The red fox and its allies (*Vulpes*) is of small size, seldom exceeding 14 pounds, with low slender skull, the interorbital region being nearly flat. The tail is large and bushy. The genus occurs from the Arctic to Central America. The gray fox (*Urocyon*) has shorter ears than the preceding genus, the fur being much coarser. There is a concealed mane of stiff hairs in the tail. The genus occurs in Eastern and Western United States south into Mexico. It is rapidly extending its range northward. The wolves (Fig. 18) and coyotes (*Canis*) are large, with deep and heavy skull, the interorbital region

being thickened and elevated. The teeth are heavy and large, the canines being particularly robust but not especially elongate. They are distributed generally throughout the northern part of North America but are scarce in the east, where they have been largely exterminated.

Family Felidae (Cats)

All cats are at once distinguished by the characteristic large cheek teeth, a distinctly trenchant type, their crowns compressed and high, without crushing surfaces, the last upper

FIG. 19.—Skull of a bobcat. The dentition is highly specialized for a meat diet, the premolars having high crowned shear like edges.

premolar and first lower molar presenting the extreme phase of carnassial modification (Fig. 19). The upper molar is narrow, the main axis of its crown transverse to the tooth row. The auditory bulla is always highly inflated. Cats are usually slender animals, the legs being moderately long and the size medium to large. Our native cats are widely distributed in North America, from well within the Arctic Circle to Panama.

The lynx and bobcat (*Lynx*) are distinguished by their moderate size and very short tail and ear tufts. The genus has but 28 teeth. They are widely distributed from the Arctic Circle to Mexico. The mountain lion (Fig. 92) and jaguar

(*Felis*) are large of size with a long tail and 30 teeth The former was once distributed over the entire United States but is now found only in Florida and the West and into southern South America The spotted jaguar probably does not occur in the United States today, but occurs with its smaller cousin, the ocelot, throughout Central America and much of South America The Yagouaroundi is a small Central American representative of this genus

ORDER PINNIPEDIA

The seals and their allies differ mainly from the Carnivora in the structure of their limbs, which are modified for aquatic progression, the humerus, radius, and ulna being short and partly enveloped in the integument of the body The feet are modified and fin like, much expanded and webbed The teeth are specialized, the molars being uniform in character, with conical, compressed pointed crowns, often with accessory cusps placed before or behind the principal ones (Fig 28) The ears are much reduced or absent, and the tail may be very short or, in the hair seals, absent The hair is either coarse (hair seals) or of the finest fur (*Callorhinus*) The order is widely distributed along the east and west coast of North America

Family Otariidae (Eared Seals)

The eared seals have hind limbs capable of rotation forward, and the fore limbs are nearly as large as the hind legs Unlike the hair seals, eared seals have small ears and long necks In North America, the family is represented only on the Pacific Coast, from Bering Sea to Lower California The important fur seal (*Callorhinus alascanus*) of commerce and the sea lion of the circus and zoo are included in this family

Family Phocidae (Hair Seals)

Unlike the eared seals, the members of this family have hind limbs relatively useless for progression on land, these members

being incapable of forward rotation Hair seals have no external ears and the hair is coarse, with no underfur Other distinguishing characteristics are the dorsal position of the nostrils and the pointed upper incisors The family has representatives from the Arctic Ocean south along the Atlantic Coast to the West Indies

Family Odobenidae (Walruses)

Walruses are characterized by their large size and the enormous canines of the upper jaw, which often reach a length of 30 inches The skin is thick and rugose, being almost hairless The tail is vestigial The walrus is found in the Arctic seas of North America

ORDER PRIMATES

The primates are a primitive generalized group which are difficult to define zoologically The members are completely hairy (except man), generally arboreal animals, with five digits on the fore and hind limbs which are usually provided with flat nails The fore feet are often adapted for grasping, as are frequently the hind feet The latter also are used for walking (digitigrade) Invariably the orbit and the temporal vacuities are surrounded by a ring of bone The clavicles are always present and well developed The apes and lemurs are very dissimilar and have been placed in separate suborders American representatives occur throughout the tropics, from Mexico southward All the New World monkeys (Platyrrhinae) are characterized by their broad nasal septum, the nostrils being directed sidewise, and by the absence of ischial callosities and cheek pouches

Family Callitrichidae (Squirrel Monkeys)

These small monkeys or marmosets are best recognized by their squirrel like appearance (Fig 20) They resemble squirrels in form, posture, and activity The long soft fur is often elongated in the form of a mane on the nape and sides

Excepting the great toe, the hands and feet are armed with long, sharply curved, compressed claws The long slender tail is non-prehensile The only representative in North America

Fig 20—Marmoset

is the Geoffroy Marmoset (*Œdipomidas*), which is found in Panama

Family Alouattidae (Howler Monkeys)

Howling monkeys are noted for their large size, heavy fur, and long prehensile tails (Fig 40) The hyoid bone, usually a small structure supporting only the back of the larynx, is in this family tremendously swollen into a large resonant drum The mandible is expanded vertically to care for this "music box" Howlers occur from Mexico to Panama in North America, they are likewise well represented in the forests of northern South America

Family Aotidae (Douroucoulis or Night Monkeys)

Night monkeys are strikingly different from other platyrrhines, the pelage being woolly, the eyes very large, and the animals generally similar in appearance to the Old World

lemurs (Fig 21) The long tail is not prehensile and has a small brush at its end Representatives occur from Nicaragua into South America

FIG 21 —Some monkeys of Central America A Capuchin monkey *Cebus* B Douroucouli *Aotus* C Spider monkey *Ateles*

Family Cebidae (Capuchin Monkeys)

The medium-sized capuchins have naked wrinkled faces, with short thick hair (Fig 21) The tail is long, strong, curled under, and completely covered with hair, the distal vertebrae of this organ being flattened at the end Members of this family were used to accompany street organs a number of years ago Capuchins occur from Honduras to Panama

Family Atelidae (Spider Monkeys)

The long limbed spider monkeys are surpassingly developed for an arboreal life The very long prehensile tail, naked on the underside near the tip (Fig 21), and the slender body and absence of a thumb are all suitable adjustments to a life in the treetops Spider monkeys range from southern Mexico to Panama

Family Saimiridae (Titi Monkeys)

The little titi monkeys resemble the better known squirrel monkeys but differ chiefly from these latter animals by their short pelage and the absence of any prominent crests The nails are arched but not so claw like as are those of the marmosets The long tail is hairy to the tip Titis occur in Costa Rica and Panama and are abundant in northern South America

ORDER RODENTIA

The rodents may be either terrestrial, fossorial, arboreal, or semi aquatic This group has both brain and placentation generalized, clawed feet, one incisor in each jaw (never more than total of four), which is prominent and protruding, the enamel not extending to the posterior surface (Fig 26) The masseter muscle is highly specialized, being divided into three or more distinct portions having slightly different functions The teeth never number more than 22 and the canines are always absent The fibula and tibula are always distinct The most prominent characters are the chisel like incisors, the absence of canines, and the wide diastema separating the incisors from the cheek teeth The rodents are usually of small size, but the beaver may attain to 60 pounds and the capybara equals a small pig in size The rodents have a world wide distribution and have representatives in every part of North America

Family Sciuridae (Squirrels, Marmots, Etc)

The squirrel family have slender or robust bodies, dependent upon whether they are adapted to an arboreal or to a terrestrial life They are well furred animals, with densely haired tails The four rooted molars of each jaw are fundamentally tritubercular, the upper incisors are long and have deep roots which terminate in front of the anterior cheek teeth Squirrels are distributed widely throughout North America, from Alaska to Panama

The woodchucks (*Marmota*) are heavy, robust, well furred animals (Fig 62) The fore feet have four toes and a rudimentary thumb with strap-like claw The skull is broad and depressed, with prominent postorbital processes The arboreal squirrels (*Sciurus*) have long, flattened, well furred tails The skull has a prominent convex brain case with slender posteriorly directed postorbital processes The genus is

widely distributed throughout temperate North America south to Panama

Family Geomyidae (Pocket Gophers)

The pocket gophers are admirably constructed for a life underground (Fig 52) The ears are minute and the eyes small and external cheek pouches are present The fore limbs have tremendously enlarged digging claws and the naked tail has a tactile tip The skull is large, heavy, and angular with widespreading zygomatic arches and a sturdy rostrum The large heavy incisors protrude The cheek teeth are persistent, with enamel plate always present on the anterior surface in upper teeth and on the posterior surface of lower teeth The family is found from Saskatchewan south to Costa Rica, but is most abundant in Western United States and Mexico

Family Heteromyidae (Pocket Mice, Kangaroo Rat, Etc)

These mice are small, with tiny fore feet and elongated hind feet, adapted for a saltatorial life Fur lined cheek pouches are always present The tail is long, and often tufted at its tip The skull is remarkable for its long rostrum and enormously inflated temporal region The family is best represented in Western North America, but occurs from British Columbia to Panama

Pocket mice (*Perognathus*) are small desert rodents, with very long tails, hind feet and fur lined cheek pouches The pelage is characteristically spiny or bristly These plain colored little rodents occur in Western America wherever desert or semi-desert conditions prevail The kangaroo rats (*Dipodomys*) are large headed desert rats, which are best recognized by their long tufted tails, greatly elongated hind limbs and striking color pattern The hind feet and toes are furred beneath These rats are widely distributed in Western North America, from Oregon and Wyoming to Mexico.

Family Castoridae (Beavers)

The familiar beaver scarcely needs description, the characteristics of the genus being those of the family. Beavers are large, heavily built animals with broad, scaly tails flattened from above and prominently webbed hind feet—adaptations for a semi-aquatic life. In addition, the skull has a broad deep rostrum and narrow brain case. The beaver is unlike most other rodents in that the hypsodont molar teeth show little wear with advancing age. The family is widely distributed from Alaska and Newfoundland to Mexico and appears to be rapidly reoccupying territory from which it was once completely extirpated.

Family Cricetidae (Native Rats and Mice)

American rats and mice are characterized by their small well-furred bodies and usually sparsely haired tails, which may be either short or long. The family includes many diverse groups and cannot be recognized by external characteristics alone. The most prominent features of the skull are the absence of postorbital processes on the frontal bone and the enlarged and specialized infraorbital foramen. The cheek teeth are the best stamp of the family. These always number three in each jaw, the crown structure showing all stages from brachydont to ever-growing. The fundamental structure is quadritubercular. The enamel patterns vary from simple heptamerism to excessive specialization, the tubercles in the maxillary teeth always presenting a longitudinally biserial arrangement and *never developing a functional third series on the lingual side of the crown*. American rats and mice are widely distributed over North America, from the Arctic to Panama.

Deer mice (*Peromyscus*) are well known to every naturalist, for there are more forms included in the genus than in any other mammalian genus of North America. The long bicolored tails, large ears and eyes, and soft brown fur above and white

fur below are distinguishing characters Internal cheek pouches are present The skull is long and delicate, with smooth thin-walled brain case Deer mice are widely distributed over the entire North American continent from the northern limits of tree growth to the high forests of Panama The wood rat (*Neotoma*) has a long, hairy or often bushy tail, large membranous ears, and a long, angular, heavy skull The molariform teeth are flat-crowned and thrown into prismatic folds The several genera of wood or pack rats are generally distributed in Western United States from northern British Columbia south into Central America, in Eastern United States from New York to Florida Field mice (*Microtus*) are small, short-tailed, rather coarse-furred voles They possess rootless molars, which grow from persistent pulps, the root of the lower incisor forming a noticeable protuberance on the outer surface of the ascending portion of the mandible at the base of the articular process These voles are widely distributed over North America north of the tropics

Family Aplodontiidae (Mountain Beavers)

The peculiar burrowing mountain beaver is a robust, medium sized rodent with short legs and vestigial tail (Fig 22) The skull is peculiar, it being greatly widened posteriorly, the auditory bullae are flask-shaped with neck directed horizontally downward The mountain beaver has a limited distribution, being found only along a narrow strip of the Pacific Coast from southwestern British Columbia to California

Fig 22 —The Mountain beaver (*Aplodontia rufa*)

Family Zapodidae (Jumping Mice)

The jumping mice are small, saltatorial mouse-like animals, with very long tails, elongated hind legs, and small ears and

eyes The metatarsals are neither reduced nor fused The cheek teeth vary in number from $\frac{5}{4}$ to $\frac{3}{3}$, the upper incisors being grooved The family is distributed over North America south to the Carolinas and New Mexico

Family Erethizonidae (Porcupines)

American porcupines are large rodents immediately distinguished from other mammals by their highly developed spines, which are narrow, pointed, barbed, and loosely attached to the skin The feet are noticeably adapted for an arboreal life The cheek teeth are very complex and flat crowned The skull has a very large *infraorbital foramen* (Fig 26) The family is distributed throughout forested Northern North America south to Panama

The tree porcupine (*Coendou*) of tropical America has a long prehensile tail, which is singularly adapted for coiling about branches by virtue of *its naked dorsal tip* The genus occurs from Mexico to Panama The Canadian porcupine (*Erethizon*) is distinguished by its short stumpy tail, robust body, and thick covering of well-developed spines It is found in the Northern portions of North America, south in the mountains to Arizona

Family Echimyidae (Spiny Rats, Hutias)

These small or medium sized rodents have harsh fur, frequently mixed with spines, and a tail which is generally long The characters are not dissimilar from the preceding family, although the feet are not adapted for an arboreal life These animals are met with in Central America and the West Indies

The spiny rats (*Proechimys*) are large terrestrial rats with grooved spines or bristles mixed with the hair, especially of the back The hutias (*Capromys*) are long-tailed, partially arboreal rodents which are notable for their restricted dis

tribution, most of the species being found on the islands of Cuba and Jamaica

Family Dasyproctidae (Agoutis)

The agoutis are large tropical rodents with hoof like claws, short ears, and an abbreviated tail The long incisors are reddish, the molars are semi rooted, with external and internal enamel folds These animals are found from southern Mexico to South America, including the Lesser Antilles

Family Cuniculidae (Spotted Cavies)

The spotted cavies do not differ greatly from the agoutis in external appearance (Fig 23) They are heavier animals

Fig 23 —Spotted cavy (*Cuniculus paca*)

and have five toes rather than three The jugal arch is extra ordinarily broad and sculptured Spotted cavies are found from southern Mexico to Panama

Family Hydrochoeridae (Capybaras)

Capybaras are the largest of existing rodents, attaining a length of 3 feet (Fig 47) The robust body is covered with coarse hair The huge skull carries a most remarkable set of teeth The strong white incisors are grooved and the cheek teeth are composed of obliquely placed, close-set plates of enamel which resemble those of an elephant The

single North American representative, *Hydrochoerus isthmius*, is found in the coastal swamps of eastern Panama

ORDER LAGOMORPHA

The lagomorphs differ from the rodents in the presence of four upper incisors, the first pair is large and suggestive of the single pair in rodents, while the second pair is small, without cutting edge and nearly circular in outline The distance between the mandibular tooth rows is not so great as that hetween the maxillary tooth rows, there is thus only one pair of rows capable of opposition at the same time the motion of the jaws being lateral The incisive foramina are very large and conflnent posteriorly, the facial portion of the maxillary is incomplete The body is well furred, with a very short tail The order is found throughout North America south to Panama

Family Ochotonidae (Pikas)

Pikas are small rabbit like animals of the rocky slopes of Western mountains (Fig 53) They have short broad, rounded ears, a vestigial tail, and digitigrade hind limbs which are not elongated as in their allies, the hares Pikas occur in the mountains of Western North America from Alaska and Alberta south to Mexico

Family Leporidae (Hares and Rabbits)

The leporids are well furred animals, with elongated hind limbs and long ears The palatal bridge is formed chiefly by the maxillary bone A prominent supraoccipital process is present The family has representatives throughout North America, from northwestern Greenland through Arctic America to Panama

The hares (*Lepus*) have robust postorbital processes their outline distinctly triangular The young are born in an advanced state the eyes open and the body well furred The rabbits (*Sylvilagus*) have long narrow postorbital process

closely applied to the side of the cranium The young are born in a naked, helpless condition Cottontails occur throughout the United States south to Panama

ORDER ARTIODACTYLA

The artiodactyls have the first or inner digit suppressed, so that the functional toes number four, or, more often, complete suppression of all but two toes, the third and fourth The terminal phalanges are flattened or concave on the inner surface, so that neither is symmetrical but forms a hoof, permitting a digitigrade condition The cheek teeth are dissimilar, the premolars being single and the molars two-lobed The molars are broad-crowned, with ridged grinding surfaces The testes are permanently carried in a scrotum Members of the order are usually of large size and essentially herbivorous Artiodactyls are distributed throughout North America

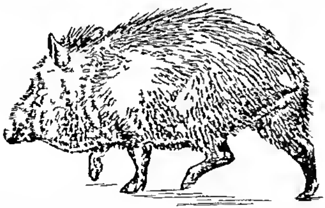

FIG 24 —The dorsal gland of the collared peccary situated above the hips often shows prominently The musky effluvium from this gland may be detected at considerable distances

Family Tayassuidae (Peccaries)

Peccaries are small pig like animals (Fig 24) having rooted incisors, the upper canines being directed downward, with a sharp cutting hind edge The fore feet have four toes,

the fifth toe being wanting, but the hind feet have only three Peccaries are found from Texas and Arizona to South America

Family Cervidae (Deer)

Bony antlers are present in the males, rarely in the females (caribou) The upper incisors are lacking and there are no canine-like premolars, the upper canines are usually absent There are three lower incisors on each side with an incisor like canine in contact with them Representatives of this family are usually of large size The family is represented from the Arctic to Panama

The moose (*Alces*) is very large, with tremendous palmate antlers, a broad pendulous muzzle, and long pointed hoofs The genus occurs in Northern North America from the forested arctic regions to Maine and Wyoming The deer (*Odocoileus*) is the smallest of American cervids It has well developed antlers with only a short brow tine The vomer rises high posteriorly and divides the posterior nares into two distinct portions The genus is generally distributed throughout Eastern and Western United States south to Panama

Family Antilocapridae (Pronghorns)

The pronghorn antelopes of both sexes have deciduous horns on permanent bony cores (Fig 34) These horns are somewhat compressed and have a single branch inclining forward Lachrymal and tarsal glands are absent The hair is brittle and pith like The animals occur in the prairie regions of North America, from Saskatchewan and Alberta south into Mexico

Family Bovidae (Bison, Sheep, and Goats)

Both sexes of this family have true horns The horns are permanent, conical, often curved, bony processes of the frontal bone, ensheathed in epidermal fibrous true horn The upper incisors and canines are lacking The stomach has

four complete compartments Representatives occur from North Greenland to Mexico

The musk-ox (*Ovibos*) is a medium sized beast with coarse shaggy hair (Fig 43) The horns curve downward, then upwards and forwards, being almost united at their base, where they are depressed and rugose These animals may fairly be said to be a connecting link between the goats and oxen Musk-oxen are found in arctic America from Greenland to Alaska, where they have been introduced The white mountain goat (*Oreamnos*) is about the size of a large domestic goat, with small black horns which curve slightly backward The long shaggy coat, beard, and short tail are characteristic of the genus They range from the Alaskan coastal ranges south in the Rocky Mountains to Idaho

ORDER PERISSODACTYLA

The odd toed hoofed animals have the middle or third digit of both fore and hind feet larger than any of the others and symmetrical in itself The cheek teeth form a continuous series, with massive, quadrate, transversely ridged or complex crowns The stomach is not complex The only American representatives in North America are found from Guatemala to Panama

Family Tapiridae (Tapirs)

The large tropical tapir is best characterized by its scantily haired thick skin and flexible mobile snout or proboscis which is formed by the nose and upper lip The fore feet have four digits, while there are but three on the hind feet Tapirs are found from Guatemala to northern South America (Fig 25)

ORDER XENARTHRA

These primitive mammals have imperfect, persistent cylindrical teeth, which are devoid of enamel The dentine is of varying hardness within the tooth, causing uneven wear

The teeth are variable in number but always homodont The bizarre and heterogeneous members of this order are of small to medium size and are found from Southwestern United States to Panama

Family Bradypodidae (Three-toed Sloths)

The arboreal sloth has three strong recurved claws on each foot, the fore limbs being greatly longer than the hind limbs

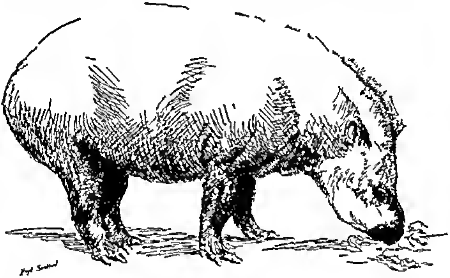

Fig 25—Tapir

The stomach is rather complex These apocryphal creatures have nine cervical vertebrae They range from Nicaragua to Panama

Family *Choloepodidae* (Two toed Sloths)

Externally these animals are very similar to the preceding family, except for the two claws of the fore feet and the presence of six or seven cervical vertebrae The anterior teeth of both jaws are separated from others by a diastema which wears them to a sharp beveled edge against the opposing tooth Two-toed sloths occur in Costa Rica and Panama

Family Myrmecophagidae (Anteaters)

The curious anteaters are the only toothless American edentates. The long snouts conceal the protrusible viscid tongue, which is used to collect insects, particularly termites (Fig. 44). The fur is thick, and the animals are equipped with powerful claws to break down anthills or to tear away bark when in search of prey. Anteaters are terrestrial and arboreal. They are most abundantly represented in South America, but range northward to Mexico.

The two-toed anteater (*Cyclopes*) is a small arboreal species, characterized by two toes on the fore limb, a soft and silky pelage, and a prehensile tapering tail. The genus ranges from Mexico to Panama. The three-toed anteaters (*Tamandua*) are rather small animals, with three toes on the fore feet, a long prehensile tail, and relatively coarse fur. Tamanduas are distributed from Mexico southward. The great anteater (*Myrmecophaga*) may at once be recognized by its strikingly marked body and its bushy horse-like tail. It is found in Costa Rica and Panama.

Family Dasypodidae (Armadillos)

Armadillos have a skin composed of bony plates, forming a hard shield on the dorsum, few hairs, and strong claws adapted for digging. The animals are all relatively small. Armadillos range from Texas south to Panama.

ORDER SIRENIA

Sirenians are at once distinguished by their paddle-shaped fore limbs, the digits enveloped in a common cutaneous covering, and by the absence of hind limbs. The tail is flattened and horizontally expanded. The skin is tough, rugose and sparsely haired. The skeleton is unusually massive, the bones of the skull and ribs being extraordinarily heavy.

Family Trichechidae (Manatees)

The manatees possess but six cervical vertebrae, thus differing, with the sloths, from all other mammals. The tail is entire, being rounded or shovel shaped. In habits they are fluviatile, occurring from east coastal Florida and the West Indies to Panama and South America.

ORDER CETACEA

Cetaceans are the most perfectly aquatic of all mammals. Externally they are fish like in form, the anterior limbs modified into fin like paddles and the posterior limbs absent, represented only within the body by skeletal rudiments. The tail is formed into horizontal flukes. The nostrils are situated far back upon the skull, represented by a single or double blowhole. The bones are all much impregnated with oil. The skin is all but hairless, smooth and shiny, covering a thick mass of blubber. A dorsal fin is often present. The eyes are minute and there is no external ear. Cetaceans are cosmopolitan, inhabiting all oceans.

SUBORDER MYSTICETI (Whalebone Whales)

Members of this suborder have no functional teeth. In their place are plates of whalebone (baleen), which are attached to the palate. The lower jaws are connected at the symphysis by fibrous tissue. The longitudinal nostrils are paired.

Family Balaenidae (Right Whales)

The right whales lack a dorsal fin and possess no grooves on the throat (Fig. 30). The head is extraordinarily large, at least one-fourth of the entire length. The cleft of the mouth forms a curved line. Right whales are restricted to circumpolar seas as the North Atlantic and North Pacific.

Family Rhachianectidae (Gray Whales)

Gray whales have small heads, elongated bodies, and narrow pectoral fins, the dorsal fin is absent and the throat smooth The mandibles are heavy and bowed outward Gray whales are distributed along the North Pacific south to Lower California

Family Balaenopteridae (Finbacks Rorquals and Humpbacks)

Tremendous size characterizes the members of this family The head is small and a dorsal fin is present, but the most conspicuous character is the presence of numerous longitudinal grooves on the throat (Fig 50) These whales are found off the Atlantic and Pacific coasts of North America

SUBORDER ODONTOCETI (Toothed Cetaceans)

Odontocetes are provided with teeth, often numerous, which are rarely non functional Baleen plates are absent The skull is not symmetrical The nostrils form a single blowhole The lower jaws are firmly joined by a symphysis

Family Physeteridae (Sperm Whales)

The upper jaw of the sperm whale is toothless, but the slender mandible is provided with many conical teeth The head is tremendous and contains an oil filled reservoir Sperm whales occur in both the Atlantic and the Pacific

Family Kogiidae (Pygmy Sperm Whales)

These are small whales seldom exceeding 14 feet A falcate dorsal fin helps to distinguish them The blowhole is crescentic and there are but two teeth in the upper jaw The family is cosmopolitan

Family Delphinidae (Porpoises, Dolphins, etc)

All the members of this family are small or medium in size never exceeding 30 feet The teeth are usually numerous

present in the upper as well as the lower jaw, and the rostral portion of the skull enlarged

The white whale (*Delphinapterus*) is best characterized by its white or very light color and by the eight or ten teeth which occupy only the anterior part of the jaw The cervical vertebrae are free and unjoined The white whale or beluga occurs in the Arctic Seas of North America The narwhals (*Monodon*) *have lost all teeth but one, this appearing as a* single twisted elongate tusk in the upper jaw which is rudimentary in the female The genus is confined to the Arctic Seas

Family Ziphiidae (Beaked Whales)

Beak whales have only one or two teeth, these being con fined to the lower jaw The muzzle is prolonged and the throat grooved Beaked whales are restricted to the North Atlantic and North Pacific oceans

BIBLIOGRAPHY

1) Linnaeus C 1758 Systema Naturae Stockholm
2) Trouessart E L 1898 1899 Catalogus Mammalium Berlin
3) Poole Arthur J 1936 *Jour Mammalogy* 17 282
4) Miller Gerritt S Jr and James W Gidley 1931 Smithsonian Scientific Series No 9 New York p 220

CHAPTER III

SOME CHARACTERS OF MAMMALS AND THEIR USES

In defining a mammal, it is sufficient to state that hair is present at some stage in its existence and that the female is equipped with cutaneous mammary glands, which secrete milk for the nourishment of the young. There are other prominent structural characters which are peculiar to mammals. The persistent left aortic arch forms the only connection between the heart and the dorsal aorta, whereas in the bird it is the right aortic arch which joins with the aorta. Among the forerunners of the mammals, the reptiles possess both a right and a left aortic arch, imperfectly connected so that blood can pass from one side to another. The red blood corpuscles lose their nucleated condition early in life so that the normal red blood cells of mammals are non-nucleated. A muscular diaphragm crosses the body cavity of mammals just behind the pericardium and lungs. It aids in respiration, the muscles contracting it allow for enlargement of the pleural cavity and thus draw air into the lungs. The bones of the skull are much reduced, lacking a prefrontal, postfrontal, quadratojugal, and some other bones, while the two occipito-condyles are formed entirely by the exoccipitals. The lower jaw is composed of a single bone, the dentary. The ear bones are composed of three small elements, the malleus, incus, and stapes. The brain is

characterized by four optic lobes. Other characteristics are very nearly universal and are usually quite distinctive. Such are the presence of seven cervical vertebrae (exceptions being the anomalous sloths and the manatee), the preacetabular attachment of the pelvis to the vertebral column, a cruro tarsal ankle joint, the presence of cartilaginous intervertebral disks which separate the centra of one vertebra from another, and the thecodont teeth, which are embedded in an alveolar pit in the jawbone.

To these might be added some other structures which appear to be peculiar to mammals. All are ably discussed, however, in anatomy texts. Inasmuch as this volume is concerned primarily with the habits of mammals, it seems desirable to discuss in detail only those structures which have to do with the animal and its environment. External characteristics are thus emphasized to the exclusion of internal structures (teeth excepted), however important the latter may be in determining the behavior of the individual.

TEETH

The dental system of mammals plays an important part in the economy of their lives. Teeth, except in a few (whalebone whales and anteaters among North American mammals) are found in all adult mammals. Teeth are tegumentary or dermal structures and in some lower vertebrates pass through invisible transitions to the hardened scutes which form the integument covering the body. Among the mammals they are limited to the dentary, premaxillary, and maxillary bones.

Normally teeth are composed of several distinct tissues rather well defined. The center of the tooth is composed of the soft pulp, abundantly supplied with nerves and blood vessels when the tooth is young. The calcification of its outer layers forms the hard dentine, which comprises the principal part of the tooth. The dentine, or ivory, consists chiefly of calcium phosphate. Over the dentine lies a thin layer, the enamel, which may completely or partially invest the tooth

It is the hardest tissue in the mammalian body. Its partial presence on the rodent incisor allows for uneven wear and, as a consequence, the resultant chisel shaped tool so necessary in cutting the food supply (Fig. 26).

Mammalian teeth are usually heterodont, the teeth being modified along the length of the jaw to suit various needs and functions. The single rooted simple incisors may be most important, as in the rodents and shrews, or of little signifi-

Fig. 26.—Skull of a porcupine. Note the dark-colored enamel facing the front of the powerful incisors and the lighter dentine behind. Differences in hardness allow for uneven wear and results in a chisel-shaped tooth admirably adapted for cutting bark.

cance and relatively undeveloped, as among certain carnivores and bats. The canines are well developed in the flesh eaters, forming tremendous tusks in the walrus, but are totally absent in the rodents. The molariform teeth assume various shapes, often sharp-crowned, in the flesh-eating cats, wolves, and weasels or in the deer tribe, for breaking down the coarse cud, but are flat-crowned in mice and other gnawing mammals. There is no such differentiation of teeth among the toothed whales, their teeth comprising a series of similar single-pointed, slightly curved cones. Such a dentition is called homodont and is found chiefly in the aquatic species.

The permaneot set of teeth is normally preceded by a "milk" dentition, which is lost a few weeks after birth. The milk teeth may disappear before birth, or a very few days after (seals), while moles oever cut their permaoent dentitioo, retaioing the milk teeth throughout life. Bats are said to lose their lacteal deotition *in utero*, but there are surely many exceptioos to this state of affairs.

Teeth are subject to rapid wear aod in old animals may be worn to the gums. Those which are subjected to hard and

Fig. 27.—Malocclusion in a woodchuck skull. The incisors of both jaws may grow unhindered when they for some reason fail to meet. Occasionally their uninterrupted growth may effectively lock the jaws.

continuous usage, such as the incisors of rodents, continue to grow throughout life. The rate of growth is phenomenal, Shadle[1] observing that extrusive growth of the four incisors of the rat amounted to 20 inches in a year and to almost as much in the rabbit.

Not infrequently the rapidly growing incisor tips of rodents become broken, or a foreign substance may lodge between them. The two opposing incisors then fail to meet, and growth continues unhindered. Such instances of malocclusion are not infrequent and often result in the starvation of the afflicted animal. Such a situation is particularly prominent with wood-

chucks (Fig 27), althongh it is not unknown amoog tree squirrels, muskrats, aod rats

Uses of Teeth Teeth vary considerably with the different orders, being adapted for a multitude of uses The deotal system of aquatic mammals is modified to catch slippery fast prey, which is bolted eotire The seals have unusual sharp cusps oo the premolars which aid them io holding fish (Fig 28) The enormous development of the upper caoines of the walrus are useful io loosening shellfish from the rocks on the

Fig 28 —Dentition of the harbor seal The accessory cusps on the cheek teeth are unique

bottom of the shallow arctic seas In the narwhal (*Monodon*) two tusks grow in the upper jaw of hoth sexes, hut as a rule the left one of the male protrudes and develops into a large tusk (Fig 38) Both tusks of the female, and as a rule the right one of the male, remain included in the tissues It is thought hy the Eskimos that these formidable weapons are used in fighting, although arctic travelers state that the narwhal is very careful of its tusk Occasionally the tusk is brokeo, and in rare iostances animals are killed which have the hollow portion of the hroken tusk filled with a smaller one This further suggests that the tusk is used as a weapon

The central incisors of shrews are long and sharp and project forward, being particularly well adapted for picking up the tiny invertebrates which litter the forest floor Bats have small sharp-cusped teeth for masticating the hard exoskeletal parts of insects Bloodsucking bats (*Desmodus*) possess only degenerate molars which are almost functionless, they possess a single pair of upper incisors, crominform and razor sharp, which slit the skin of their prey The young of some species of bats have hooked teeth which assist them in grasping the

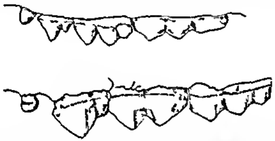

Fig 29 —The upper illustration shows the maxillary cheek teeth of a black bear Their relative bluntness suffices for an omnivorous diet of berries roots and small game Those below are the cheek teeth of a polar bear During the long winter months the chief food of this arctic bear is seals *for which the trenchant molars are well adapted*

fur and flesh of the pectoral region as they are carried about by the mother during her evening flights

The teeth of carnivores may be extremely modified, the carnassial premolar being sharp and pointed, adapted for cutting flesh Many carnivores are omnivorous and fail to show such a specialized dentition The molars of the black bear and polar bear show, in a slight way, the differences wrought by dissimilar food habits In the black bear, which feeds largely on fruit, berries, insects, roots, and small game, the back cheek teeth are flattened and well developed The polar bear, which depends in large measure on seals for its food, has shear like premolars and the rear cheek teeth are degenerate (Fig 29)

Rodents all have sharp strong incisors which are used for cutting their food supply The fossorial pocket gopher uses its large projecting incisors to tear away roots, soil, and other

obstructions when tunneling To prevent the mouth cavity from becoming filled with dirt the lips meet behind the teeth so that these appear to protrude from the mouth Indeed this is characteristic of most burrowing rodents and is readily demonstrated in the field mouse Arctic hares have protruding teeth which they employ to break the snow crust and gather lichens in the bleak world they inhabit (Fig 42)

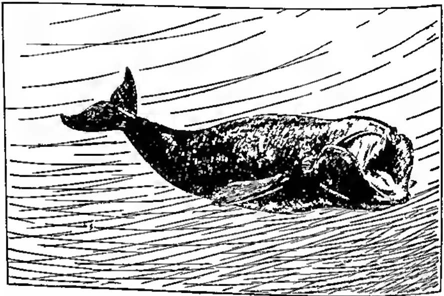

Fig 30 —The baleen plates of the right whale act as effective strainers When the cavernous mouth has engulfed quantities of small crustacea it is closed The great tongue then presses against the plates straining out the water and retaining the food

Toothless mammals possess structures which fit them for a peculiar niche their food usually being specialized Thus the edentulous anteaters (*Myrmecophaga*) have the face produced into a loog tubular rostrum from which a long flexible glutinous toogue licks up the swarming termites The whale bone whales lose their teeth before birth and secure the baleen or whalebooe some time after birth The baleen consists of a series of flattened horny plates (Fig 30) ofteo numbering 400 which hang from the roof of the mouth oo either side of the mid line The plates ruo lengthwise aloog the palate, close

together The inner edge of the plate is frayed into long bristly fibers The baleen plates are longest nearer the middle of the series and become progressively smaller as they pass toward the front or back of the mouth The baleen consists of the modified mucous membrane of the mouth When the whale fills its cavernous mouth with krill or small fish, the huge tongue raised against the whalebone permits the water to escape through the narrow intervals between the plates and rush out through the lips

HAIR

Hair is common to all mammals It usually covers the body, but may be greatly reduced in the Cetacea, where it is found as a few scattered bristles about the lips or often present only in the young In others, as the naked rat (*Heterocephalus*), the hairs are so sparse that they may be easily counted Hair is epidermal in origin, developing first as a thickening of the skin, which pushes into the corium Directly under the basal portion of this thickening a tiny cup is formed, ultimately becoming the papilla This cup is richly supplied with blood vessels and, thus nourished, proliferates new cells rapidly These in turn are forced through the skin to form the hair This ingrowth splits away from the developing hair to form the hair follicle, while yet another ingrowth from the follicle provides a sebaceous gland, the secretions of which serve to render the dead hair less brittle The hair normally consists of three well-defined layers The medulla, or pith, occupies the center of the hair and is composed of shrunken cells of dried epithelial structures Surrounding this pith is the cortex, composed of a rather transparent mass which occupies the bulk of the hair Within the cortex are scattered minute pigment granules which give color to the hair Surrounding these inner layers is the cuticle, composed of colorless scales arranged in an imbricate fashion and often beautifully sculptured The hair may be circular or elliptical in cross section Flattened hairs are curly, while

those which are circular are normally straight or but little curved

Mammals usually possess two types of hair, the underhair, which lies next the skin and is thick and soft, and the guard hair, which is relatively coarse and lies over the underhair, forming a protective coat These two types are well illustrated in the majority of fur bearing animals Not a few mammals possess several kinds of hair, and practically all possess the easily recognized and specialized tactile hairs, or vibrissae The hair is shed annually or may be shed twice each year, although there is evidence that some hairs, such as the mane of a horse, persist throughout life When the hair ceases to grow, it is pushed out as the root again commences to proliferate new cells

The hair serves many uses, none of which are more important than its heat retaining qualities The air imprisoning pelt retains body temperatures and acts as an insulating agent, allowing scant opportunity for cold outer air to reach the sensitive skin Northern mammals usually have thinner hides and denser fur than their southern relatives This characteristic is particularly noticeable in such a form as the muskrat Those from the Louisiana marshes are provided with a heavy hide and thin fur in marked contrast to the thin hide and dense fur of the same species at the northernmost limits of its range

The hair plays an important role in many other ways Ungulates use their hairy tails to remove troublesome insects The bushy tail of the fox guards its face when the animal is coiled in sleep Certain hair patches, such as the rump hairs of the pronghorn or the white haired tail of the Virginia deer, are used by the animal apparently to apprise their fellows of approaching danger or serve to guide members of a herd through the forest when precipitous flight becomes a necessity Squirrel monkeys are sensitive to the cold, and will wrap their long hairy tail about their necks thus insuring a measure of warmth in this singular manner If the

weather be cold, the members of a group crouch together in a ball, covering each other with their tails

COLORATION

Mammals are usually clothed in somber colors, seldom rivaling the brilliant plumaged birds Color is chiefly determined by the pigmented hairs, for only in a few species is an appreciable amount of bare skin visible When such occurs the flesh may be of a brilliant hue, such as is found on the cheeks and the sternal callosities of the mandrill Once the hair is formed, the pigment may undergo a slight fading, but this is not significant and cannot appreciably alter the color of the animal Thus any change which may be effected must be brought on by a molt, which often produces quite a different appearance in the animal Weasels, snowshoe hares, and some lemmings may wear a brown livery during the summer but don a pristine coat of white as cold weather sets in Some shrews forsake their dull brown coat for a rich gray one as fall approaches Desert mammals are notably pale-colored, while their relatives of the humid coastal belt or neighboring mountains tend to be dark

Many theories and observations have been advanced which suggest that the colors of mammals are protective in function and have been produced through natural selection The coat color of most small mammals tends to approximate the color of the environment, this is prominently illustrated in those species which inhabit the striking environments of Southwestern United States Here are found sizable areas of white sand dunes and black lava flow The mice which are isolated on these areas tend to parallel them in color Benson* believes that none of the physical factors of the environment, save that of color, appear to be correlated with the colors of the animals Inasmuch as there is scant probability that the color of the background can directly affect the color of the mammals which live upon it, there is little probability that the colors of the races are due to the direct action of any one

of the environmental factors It would appear that natural selection is operating to produce protectively colored species Thus the color of the background, through natural selection, might conceivably be an important factor in determining the color of mammals But there are several important objections to this theory Many protectively colored animals are nocturnal, others, such as the pocket gophers, spend the greater part of their lives below ground, yet their coat colors approximate rather sharply the color of the soil in which they live Sumner[3] believes that depigmentation rather than concealing coloration per se is the thing which results from life in arid regions Sumner collected a large series of mice (*Peromyscus crinitus*) on extremely dark lava beds, which contrasted sharply with the pale sand and gravel that surrounded it He then secured another series from an area devoid of lava fields or other extensive masses of dark rock When critically compared the two series revealed no obvious or constant differences in their average color tone Thus climatic factors, rather than the optical properties of the background, appear to be responsible for the differences of color between the mountainous and desert country The most important of these appears to be atmospheric humidity

Much stress has been placed on the value of protective colors, colors which warn, ruptive marks which help to break up the outline of the body, and so-called directive or flash markings The survival value of these is problematic There are habits, however, associated with ability to modify or apparently change the color of the animal that cannot pass unnoticed and illustrate the difficulty of proper interpretation In Southwestern United States, the large antelope jack rabbit (*Lepus alleni*) is remarkable for its striking color pattern This jack rabbit is characterized by a dark buffy mantle covering the top of the back and sharply outlined by whitish or iron gray sides and rump, the light-colored sides being continuous with the white of the belly By means of muscles the loose skin of either side can be drawn over the back at

will In this manner the dark dorsal area is shifted almost completely to one side and the white on the opposite side is drawn nearly or quite to the median line of the back This happens whenever the rabbit is frightened, and occurs always on the side toward the intruder In the bright sunlight the snowy white side flashes brilliantly, attracting attention from afar, and affording a fine example of directive coloration [4] The rabbit may zigzag along, changing its course every few yards, and at every turn the white side is flashed on the

FIG 31 —The flashing white rumps of a startled antelope band offers a striking spectacle The hairs of the rump are raised when the animal is alarmed and act as a warning to other members of the band (*Photograph by Edmund Heller*)

observer If it can be demonstrated that a quick change is often made, resulting in a total disappearance of the pursued rabbit by contraction of the skin muscles so that an obliterative effect results, then the purpose of such behavior is apparent But the bright flash must attract predators as well as the rabbits own kind Moreover, the obliterative effect when employed would conceivably confuse others of the same species of the whereabouts of the jack rabbit when it came to rest

The rump patch of the pronghorn antelope is formed of long white hairs, which, when erected by specialized muscles form two great white rosettes These produce an astonishingly bright mark which may be seen at a distance of one or two

miles They may serve as a directive mark to other antelopes or may be used as an alarm when the animals are disturbed (Fig 31)

Variable Colors In northern latitudes, where definite environmental changes occur with the seasons, many mammals undergo a seasonal molt which makes them less conspicuous The weasels, hares, foxes, and lemmings all become white with the approach of snow and again don a brown or gray pelt as the snow melts in the spring There is a very definite correlation between the time and length of change of pelage color and the time and kind of average background of the environment Thus hares (*Lepus*) show considerable variation over the entire range of the genus The arctic hares of Ellesmere Island, which range even to latitude 83°, retain an entire white pelage at all seasons, except for small blackish ear tips A subspecies, the Hudson Bay hare, does not fully lose its white coat until late June and commences to turn white during late August The varying hare, in Northern United States, first shows incipient molt in early September, the complete change from brown to white occupying 70 to 90 days and the spring molt more than 2 months The changes of pelage do not appear to be correlated directly with immediate climatic changes but do show remarkable correlation with average climatic conditions particularly with the presence or absence of snow [5] At different elevations of the Green Mountains Vermont, Smith[6] has noted prominent differences in the pelage of the snowshoe hare during mid June At an altitude of 2,800 feet a hare was observed in complete summer pelage Another seen at 3,200 feet, was noticeably lighter Finally, at 4,000 feet and close to timber line, where snow often persists into May, a hare with white rump and neck and a pelage markedly lighter than the others was seen Hares of the humid rainy Pacific Coast region (*Lepus washingtoni*) never assume a white coat, *Lepus bairdi* has white feet the year round

Among arctic mammals, the little Richardson lemming (*Dicrostonyx*) becomes white, while its cousin, *Lemmus*, retains

its brownish gray garb throughout the year Yet their habitats are not dissimilar, they are not infrequently taken in the

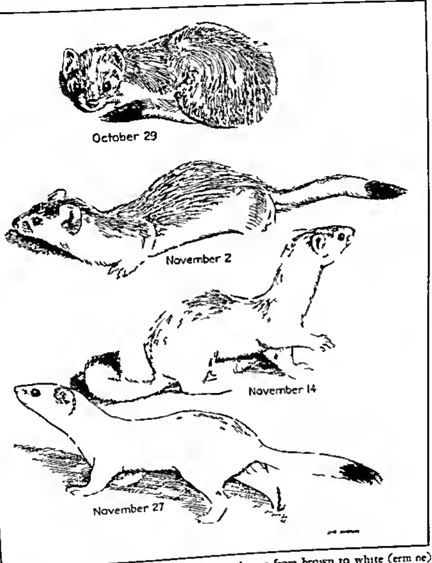

Fig 32 —The fall molt in a weasel The change from brown to white (ermine) is due to a molt and not to a change in the depigmentation of the existing hairs The molt is usually completed in a month or less

same subnivean burrow on succeeding nights The arctic fox becomes white by late fall but may retain its brownish coat

into mid winter The brown coat appears in June or July The Peary caribou of Ellesmere Island, unlike its kin, is nearly all white It retains a light-colored coat even in summer

How is the change brought about? Some believe that an actual change of pigmentation occurs in the hair or that a lengthening and blanching of the fur occur Careful studies on pelage changes of the snowshoe hare[7] and on the weasel[18] indicate that a biannual molt accounts for the color change Upon microscopic examination, no hairs were found that exhibit a partial change from brown to white Weasels shed their brown fur from mid-October to December, it being replaced by white hairs The change usually occupies from 3 to 5 weeks (Fig 32) The fall molt often is completed long before the first snow has fallen, and the vernal change to brown may be completed while there is yet a foot of snow in the woods

Dichromatism It frequently happens that there are two well-defined color phases in the same species The silver fox is nothing but a black red fox and may occur in the same litter with red brothers and sisters The cross fox, intermediate in color between the two, nevertheless does not differ specifically from the red fox Red backed mice often sport an individual which is colored so like a field mouse that, superficially, the two are distinguished with some difficulty This blackish phase may be found in the same litter with the typical red phase As the northern part of the range is approached, the black phase dominates the reddish phase The same is true for the gray squirrel, whose black phase becomes increasingly common as the northern limit of the range is approached Some bats show sexual differences in color, but such a condition among mammals is unusual

Albinism is commonly met with, the writer having seen albino opossums, shrews, moles, raccoons, skunks, wood chucks, red and gray squirrels, field mice, muskrats porcupines, and deer In addition to this, there are many records of albinism among other species, including a sea lion Melanism

is not unusual, but records of really black furred individuals appear to be far less common than albinos

ANTLERS AND HORNS

Antlers Deciduous antlers occur in the males of all American Cervidae In addition, females of caribou (*Rangifer*) are equipped with antlers These impressive osseous structures are the most rapid growing membrane bones to be found in mammals The cervine antler grows from a pedicle of the frontal bone and is covered with a true skin, the velvet, during its period of growth At birth there is no external indication of an antler, but in several months small paired bulges appear on the frontal bone of the male, growing rapidly to form the pedicle The first antler grows from this pedicle when the deer is about eighteen months old Ossification of the antler begins at the base and keeps pace with the growing tip, so that a section at any level is harder than that above it and less ossified than that below

According to Cowan[9] the antler consists of two types of bone The mature antler has a sheath of compact bone (*substantia compacta*), 7 to 10 millimeters in thickness completely surrounding it throughout its length and becoming thinner toward the tips of the tines Except at the base the core of the antler consists of spongy bone (*substantia spongiosa*) The base of the antler and the part extending for a short distance above the frontal pedicle is entirely compact bone and plays an important role in the shedding of the antler

Growth continues until the pattern of the species and individual is completed ossification not being completed until the tip has become ossified, after which the velvet is shed The antler does not increase in diameter as it grows in length except at the base [10] During the growing period the antler is capable of repair if it be injured for during this period the base or pedicle transmits blood to the interior of the antler

The growing antler is covered with skin the velvet, which is richly supplied with blood vessels These vessels appear to

anastomose but little with the underlying bony antler, maintaining only the temperature of the growing bone within the

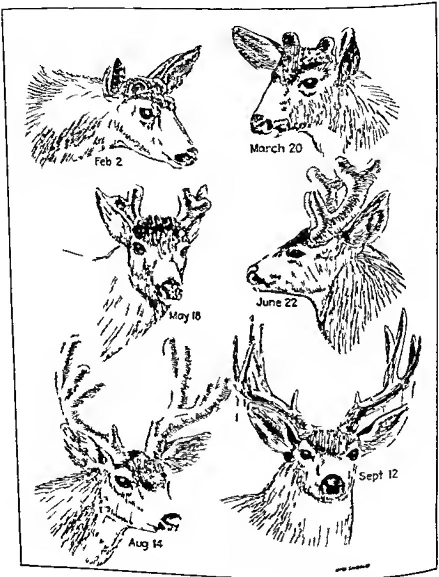

FIG 33 —Growth of antlers in the mule deer

hairy covering[11] There appears to be no separate periosteum separating the velvet from the bone, it thus lies directly upon the developing antler The rapid growth and reproduction

of the skin elements forming the velvet fully cover the great palmate antlers of the moose within 3 months Because of its highly sensitive nature, the velvet probably acts as a protective device to the growing antler

The growth of new antlers is extremely rapid (Fig 33) The incipient antlers of a bull elk in late April are hardly larger than one s hand By August they have attained the massive rack which is familiar to many A white-tailed deer which the writer had the opportunity to observe completed its entire antler growth in 14 weeks

Complete antler attainment occurs in the late summer or fall The circulation of blood in the velvet has become sluggish and is shut off The bucks then rub their rack of antlers against trees or brush until the dead skin hangs in strips from the bone, suggesting draperies of moss hanging from a limb The velvet is normally shed earlier in old bucks In Alaska on still days in early September the scraping and clanking of the antlers may be heard in scattered timber, where large bucks are engaged in polishing their antlers [14]

The first set of antlers, which commence growth when the buck is three or four months old, consist of a single spike The black-tailed deer normally has forked antlers the second year and three-point antlers in its third year After this it is impossible to predict the number of points The eastern white tailed deer may have four points to each antler the third year or may not acquire this number until its fourth year It is, of course, impossible to determine the age of the deer by the number of points its antlers support With advanced age the number of points may be reduced, and a senile individual, while of large size, may not support more than two points to each antler The smooth character of the antlers of young deer give way with advancing age to increasing roughness, so that the base of the antler in a mature prime buck may be thickly studded with osseous protuberances

After the new antlers have been carried for several months, they become loosened and fall off From the very beginning of antler formation a preparation for shedding of the antler

is in process This is caused by the constricting of the blood vessels within the base of the antler, through the rapid proliferation of the bony tissue around them, followed by necrosis Shortly before the antler is shed, the bone on the distal end of the pedicle becomes softened, blood vessels within the pedicle increase in number and size, and granulation tissue is formed, which loosens the connection between the dead antler and the pedicle The heavy antler falls off due to its own weight or accidental contact with a tree or other object, leaving a naked cavity on the tip of the pedicle The antlers of Alaskan caribou are shed in November, two months after maturing, and replacement does not usually commence until late April Eastern deer lose their antlers from mid December until March, the majority seeming to drop in late January or February

Although one might expect to find large numbers of antlers in the coverts inhabited by deer, few are found Porcupines hares and mice gnaw on the fallen bones until little is left Caribou chew and partially eat their freshly fallen antlers The pronghorns of the antelope disintegrate rather rapidly on the Western plains, few being found by man

Deformed antlers are not unusual and may often be traced to destruction of the testes, inasmuch as the antlers are secondary sexual structures and as such are governed by the hormone secretions of the gonads Velvet occasionally persists on the antlers of deer A number of records of horned does suggests that this is not an unusual condition Moore[11] has noted a relation between the molar teeth and the condition of the cervine antler A deformed antler is usually accompanied by bad molars on the same side of the head these either being decayed or greatly worn

Prong Horns The branched deciduous horns of the prong horn antelope (*Antilocapra*) are unique and warrant special attention (Fig 34) Though true horns they differ from those of the bison and sheep being branched and shed annually The horn itself is an outgrowth of and attached to the

skin of the bony pedicle and is not in direct contact with the bone itself [14]

The bony pedicle or core which supports it is actually a projection from the frontal bone of the skull When the horn is shed, the bony pedicle is exposed as a conical knob, with rounded extremity The skin enclosing the pedicle, or so-called bone core, clings firmly to the bone beneath it and apparently

Fig 34 —Pronghorn antelope

the corneum of its epidermis serves as the starting point of a new horn The epidermal horn consists of true keratogenous or horn tissue, such as one finds in all true horns The horns of *Antilocapra* differ from those of the deer tribe in that they are epidermal in origin, while the horns of the Cervidae are composed of true bone or mesodermal structures

Females are often without horns when horns are present they are much smaller than those of the males, usually not

exceeding 1 to 3 inches in length, and are unbranched. The horns are usually shed in late October or November, the vigor and age of the animal determining the time of horn loss.

Hollow Horns. The horns of the buffalo, big horn, mountain goat, and musk ox are permanent bony processes

Fig 35.—Death to the victor! This pair of white-tail bucks in their prime had met in combat. Their antlers became inextricably locked. An antler beam of the larger buck has pierced the skull and brain of the smaller. Unable to free itself, the larger buck perished miserably. The battle occurred in central New York during mid November. The ground about was torn up for nearly an acre. (*Photograph by Sgt. John H. Kel[illegible]*)

growing from the frontal sinuses, ensheathed in true horn of epidermic structure. Such horns continue to grow from the base throughout life, and are very rarely, if ever, shed. Hollow horns are present in the males and in a less developed state in the females.

Uses of Antlers and Horns The antler appears to be an offensive or defensive mechanism, useful to the deer during the rutting season, when the bucks are gathering together their harem During the fall, vicious fights occur between the males of all cervids These fights have been witnessed by a number of naturalists, and all, without exception, have remarked on the fury displayed by the animals It is usual for the bucks of deer, elk, and moose to charge at one another, endeavoring to rip or tear their antagonist with the sharp tines Not infrequently the antlers become inextricably locked and the two combatants, exhausted, suffer a lingering death (Fig 35) In fighting, the male antelope uses the prong as a guard and deftly parries the thrusts of his adversary The rams of mountain sheep use the massive horns as battering rams, two males meeting with terrific force when fighting for the favor of a ewe

It has been stated by many authors that the well-developed brow tine, or shovel, of the caribou is used by the animal to scrape away snow and uncover lichens Murie objects to this theory of use, pointing out that in only a few adult bulls are the brow tines well developed [15] Inasmuch as the tine does not extend beyond the muzzle, it would provide at best an awkward tool with which to shovel snow

TEMPERATURE OF MAMMALS

Biologists generally have attributed to mammals the power of regulating their body temperatures, so that most species are considered homoiothermic, contrasting sharply in this respect with their poikilothermous reptilian ancestors Nevertheless, some groups of mammals have an exceedingly unstable temperature regulation Others are subject to slight changes in a daily rhythm, some may have a wide range even seasonal in nature, while still others may show no variation from the normal Seasonal variation occurs in those species which have a period of torpor The fact that some

mammals lead a sluggish existence may have a further bearing on the body temperature

We might logically expect some variation to occur in primitive mammals Records of the monotreme temperatures are numerous, the most interesting being made by Simpson,[15] in which a range of 22 to 36 6°C was observed in the echidna Burrell[1] found a variation of 10°F in the wild platypus The difference between the monotreme temperature and that of other mammals is not nearly so great as it is often asserted to be

The edentates are considered primitive and exhibit variable temperatures Observations made by Wislocki[18] point out the inability of these sluggish mammals to maintain a constant temperature when placed in a cold room Two sloths (*Bradypus griseus*) at body temperatures of 91 5 F (air temperature of 79°F) were placed in a room with a temperature of 57 3°F In less than an hour the temperature of the sloths dropped to 86 F and in 5 hours the animals had become thoroughly chilled, the temperatures of the two reading 75 and 73 5°F respectively Upon continued exposure in the cold room, one sloth succumbed The other, after a period of 12 hours and with a body temperature of 73 5°F , was removed to a warmer room where the temperature was constant at 97°F In less than 2 hours the temperature of the sloth had mounted to 84 3°F The experiment demonstrates the variable nature of the temperature in this species and the ability of the species to regulate its body heat to correspond with changes of the atmospheric temperature Wislocki induced changes in the temperature of the nine-handed armadillo by subjecting it to low temperatures the drop amounting to 6 to 8°F in 4 hours, when the animal was transferred from room tempera

temperatures of 70 5 to 84 3°F respectively The rectal temperatures of the Virginia opossum which the writer has studied vary between 90 and 94°F when the animal is placed in room temperatures of 24° to 68°F

Rodents show a primitiveness in the unstable nature of their heat regulating mechanism Thus Johnson[19] found that the temperatures of active ground squirrels range from 87 5 to 105 7°F but a range of 95 to 102 5°F is common in a warm room and 86 to 95° in a cold room Spring temperatures averaged higher than fall and winter temperatures of active ground squirrels according to Wade [20] Temperatures of wood chucks obtained by the writer during the spring vary from 94 8 to 104°F , a variation of 9 2°F Young animals gave a lower reading than adults

Few temperature records of wild carnivores are available The temperature of the domestic cat varies between 101 and 104°F at air temperatures of 41 to 104°F [21] Hanna[22] states that the normal temperature of fur seals is about 101°F When the temperature rises above 103°F the animals indicate this heated condition by panting and fanning with the flippers

We thus see that many mammals possess an unusually labile temperature not at all in keeping with the exact temperatures which are customarily associated with homoiothermism

SKIN GLANDS

Integumental glands play a prominent role in the lives of mammals They are usually found variously situated in all terrestrial species The function of these glands many of which give off a prominent and characteristic scent is not well understood although there has been much conjecture about them and much value has been attributed to them The anal glands of mustelids notably the skunk serve a defensive use The secretions of the prominent glands of the musk deer are said to resemble the bodily odors of crocodiles and thus insure some measure of protection to this otherwise timid little beast Many glands enlarge during the season of reproduction

and undoubtedly serve to bring the sexes together The pedal glands of deer probably provide a means of communication between members of a herd and allow a stray individual to find its way back to the fold

Preputial glands are common to many mice, notably the muskrat (Fig 36) The glands lie on either side of the penis just beneath the skin, the ducts opening within the prepuce These glands enlarge during the breeding season, notably in the male, at which time a musky secretion is deposited on the

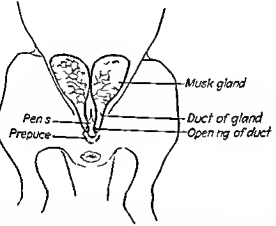

Fig 36 —The preputial or musk glands of the muskrat enlarge during the reproductive season They lie just beneath the skin and open onto the glans penis The specific odor is transferred to logs or other favorite resorts The purpose of these glands is not fully understood but it is believed that they serve to attract the sexes

feeding platforms, trails, and other resorts The natural excretions of urine *in transitu* bear with them this specific odor of the animal The secretion from the preputial gland of the muskrat is used in the manufacture of perfumery These glands, or castor bags, are enormously developed in both sexes of the beaver during the breeding season Just behind them lie large oil sacs, the secretions of which are mixed with the castoreum on prominent bars and points These are visited nightly by beavers of both sexes, which, after depositing their scent, cover it with mud It is probable that these scent sta

tions aid the beavers in finding a mate at this season The castor bags are much valued by trappers, who use the contents (castoreum) in various animal lures A century ago the castoreum was much in demand for perfumery, and many medicines were compounded from it which were reputed to cure sundry diseases

Such preputial, or protometric, glands are said to be well developed in the Canidae Wolves are reputed to have their range well laid out with signal stations or intelligence posts [23] These stations, occurring at intervals of a mile or less, may be a large rock, post, stump, or buffalo skull, usually in a conspicuous or isolated position Here the wolves repair and quickly divine, by the character of the smell, those which have last visited the post Seton believes that the main items of news essential to the life of the wolf are obtained at these signal stations

The skin glands of the deer tribe occur as preorbital, tarsal, metatarsal, and interdigital The sac like ectodermal gland which lies just before the eye in the deer seems to have little functional value in American deer, although it is capable of eversion in some genera of antelopes Its situation suggests that any secretion could readily come in contact with the shrubs upon which the deer browse The tarsal glands are marked by a tuft of long coarse hair Here the enlarged sebaceous glands produce an oily material with a pronounced ammoniacal smell Cowan[24] believes that the gland, at least in the male, has some connection with the sexual cycle of the animal He has observed bucks to urinate deliberately on the tarsal tufts The metatarsal glands secrete an oily substance with a pungent musky odor, which Pocock[25] believes serves to mark the resting spots used by the animals Many artiodactyls possess pedal glands, the American deer having interdigital glands on all feet This gland is a simple sac like structure (Fig 37) which lies between the two main digits Long hairs conduct the secretion from enlarged sudoriparous glands to the hoof These pedal glands are actively secreting

throughout the year It is possible that they scent the tracks of the individual, allowing members of a herd to find one another or permitting a doe easily to retrace her steps and thus find her fawn

The mountain goat (*Oreamnos*) has two large glands covered with black oily skin which lie at the base of and behind the horns The function of the gland is not understood, although Seton believes it attracts the sexes together during the season of rut The pronghorn antelope has prominent ischial glands, which are exerted when the animal is alarmed Indeed, many deer have such glands situated at the base of the tail In addition to these, inguinal glands, often of considerable size, are found in many ruminants

Fig 37 —Pedal glands are common to the deer tribe Their secretions are carried by the long hairs to the hoof A sagittal section between the toes has been made to illustrate this gland in the Virginia deer

The peccary has a prominent musk gland on the back, placed over the hips (Fig 24) This gland, which appears not unlike a navel (hence the generic name *Dicotyles*) produces a most disagreeable smell The writer has located a herd of these animals in the Costa Rican forest by their penetrating odor, even when the pigs have been a hundred yards distant It is probable that these glands function as a signal system, for Grant[75] remarks on their use in enabling the young to find and follow the mother The boars are said to rub the gland against low lying limbs or the trunk of a convenient tree

Anal glands are pronounced in many carnivores and are particularly well developed in the Mustelidae The skunk, mink, and weasel all have these odoriferous glands, which lie just beneath the skin on either side of the vent, the ducts of

which open into the anus When the animals are alarmed, the secretions of the glands are forcibly extruded, often to a distance of several feet Mice, shrews, and tree squirrels possess anal glands, but such structures are most prominent among the ground squirrels The large anal glands open into three white-capped orifices which are extruded from the vent when the animal is frightened Woodchucks apparently use these glands as a means of communication, particularly when they are leaving their dens [27]

In addition to those discussed above, there are cutaneous side glands of shrews, more prominently developed in the male, which actively secrete during the breeding season Field mice, especially the old males possess hip glands The opossum (*Didelphis marsupialis*) has a prominent pectoral gland, the secretion of which comes in contact with objects up which the opossum climbs Wolves and foxes have elongated caudal glands on the dorsal base of the tail

During the rutting season, many animals give off a strong effluvium At the mating time male deer, elk, and moose have a pronounced musky odor, which may be useful in attracting the females It is said that the bull moose digs a hollow in the earth with his hoofs and in it blends every substance that he is capable of extruding He then wallows and splashes in this depression In still air, the scent of these big game animals may persist for many hours The most malodorous of the entire deer tribe is the caribou When animals are excited or wounded the odor is more pronounced, and persons have become nauseated by the odor of a wounded mountain caribou [28]

Usually specialized scent glands are far more prominent in the male, but in the marmosets the female exhibits the greater development of these glands Complex scent glands in this group are located in the pubic region, on the genitalia or in the perineum Other than the Callitrichidae, none of the monkeys or apes exhibit complex scent glands of the skin[29] nor does man

A small dermal gland on top of the shoulders of the kangaroo rat has been described by Bailey,[20] it is normally concealed by the hair, but, when this is parted, the gland is conspicuous as a warty excrescence about ¼ inch long. The gland has a musky odor which appears to serve as a recognition character to individuals or species of the group and may be an important registration or property mark. Another function of the gland appears to be that of a waterproofing agent, when deprived of sand or dusty soil the animal loses its usual glossy appearance, and only in its natural habitat can it acquire enough dust or soil to absorb the excess excretion and thus keep the fur in good condition.

SECONDARY SEXUAL CHARACTERS

Other than those sex characters connected with the gonads there are characters which show occasional striking differences between the sexes of many mammals (Fig. 38). These are seldom so constant nor do they occur with such frequency as among birds and amphibia. They are generally associated with greater size and skeletal outgrowths in the male. Many of them have a functional value while others appear to have no explainable use. Sexual differences appear more marked in large mammals and, aside from greater development of scent glands, secondary sex characters may be altogether lacking in the smaller rodents, insectivores, and bats.

The male of the species is often markedly larger than the female. Such is notably true of the Pinnipedia. Large fur-seal bulls may weigh 600 pounds, while mature females average 50 to 100 pounds. We likewise find remarkable disparity in size between the sexes of the sea lion and elephant seal. During the breeding season the necks of the males are greatly swollen, this being characteristic of the deer tribe as well. The males of weasels and mink greatly exceed the females in size, often weighing twice as much as their mates.

The male hood seal (*Cystophora*), as its name implies, has on the face an inflatable bag of muscular tissue, while the


A
B
C
D
E
F

male elephant seal has a long pendulous nose capable of inflation

Antlers are common to the deer tribe, but, except in the caribou, are carried only by the male

Scent glands are often more prominent in the males, this being notably true of the shrews and mice The enlargement of these glands usually accompanies the season of reproduction

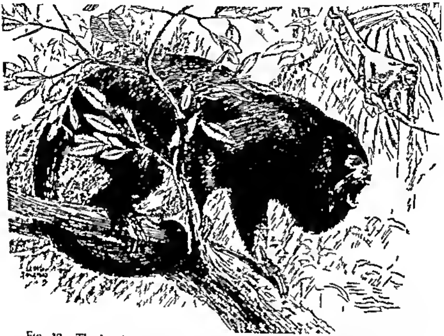

FIG 39 —The howler monkey shows sexual differences in color the male being black and the female a dirty yellow The larynx is tremendously developed The throaty chorus of these big monkeys is one of the most inspiring sounds of the Panamanian jungle

Teeth are sometimes extraordinarily developed in the male A classic instance of this is the narwhal In this cetacean all the teeth except two remain in a rudimentary condition These two teeth lie in a horizontal position in the maxilla, in the female they remain actually within the alveolus, so that the animal appears toothless In the male the right tooth

likewise remains abortive, but the left is greatly enlarged, sometimes attaining half the length of the entire animal This long cylindrical tusk is marked by spiral grooves The function of this great tooth is not understood

Unlike birds, mammals seldom exhibit sexual variation in color, but there are some species which show a sexual variation in a striking manner The male howler monkey is black, while the female is yellowish (Fig 39) The male hare-lipped bat (*Noctilio leporinus*) of Panama is said to be deep rufous above and bright orange rufous below, but the pale females lack the rufous tints, being olive brown above and yellowish below The two sexes of our common red bat show marked dissimilarity in color, the males being bright rusty while the female is chestnut-hued

CHAPTER IV

ADAPTATIONS

Any sufficiently large area varied in topography, climate and vegetation will, *in geologic time*, give rise to a diversified fauna This is amply demonstrated in the island continent Australia, where one finds carnivores, herbivores, and burrowing, terrestrial, and arboreal forms, all recognizable, on close inspection, as members of the *Marsupialia* These forms are paralleled in distant lands by species which show no close relationship to them but approximate in external characters the primitive beasts of Australia

Adaptive response to the environment is visible everywhere So easily does the environment mold a form that often two species, widely separated phylogenetically, appear to be closely related Some scientists believe, for example, that the Cetacea are diphyletic from quite different sources and that the supposed relationships between the toothed whales and the baleen, or whalebone, whales are merely parallelisms due to the similarity of the environment This has resulted from the profound modifications which *life in the water* produces, affecting internal as well as external structure and leading to striking similarities in many structures in groups which are not genetically related Space does not permit enumeration of the bases for this reasoning but there is much which favors such a view

AQUATIC MAMMALS

Modification for an aquatic existence may be observed in many mammals, from such a marine leviathan as the whale, which spends its entire existence in the water, to the tiny water shrew, whose fringed toes aid it on occasional sojourns to the stream bottom Between these two forms are a host of species which illustrate diverse adaptive development for a partial life in the water While positive proof is lacking, we may feel assured that all aquatic mammals, however extreme their adaptations may be, are all descended from terrestrial ancestors The profound changes which have occurred in the whale, both internal and external, are difficult of interpretation, but, even though they be vestigial, all the organs of a terrestrial mammal are present

Swimming is accomplished in a number of ways Undulatory movements of the body and tail base are employed by the otter and the majority of cetaceans, but a great many aquatic species use the appendages Thus all the limbs are used by the walrus and polar bear, both of which are strong but relatively slow swimmers The fore limbs are employed in swimming chiefly by the fur seals and sea lions Propulsion is accomplished by pelvic appendages in the water shrew, sea otter, hair seal, and all aquatic rodents, as the beaver, muskrat, and water vole Some mammals (*Condylura*) use the tail as an accessory scull when swimming

The external features of aquatic mammals are variable Those which are restricted to the water assume a fish like form, streamlined in most particulars The swiftest of cetaceans assume such shape This must be close to the ideal, for it is approached in almost identical degree by three diverse class of vertebrates—the porpoise, ichthyosaur, and certain sharks [1]

In those mammals which become increasingly dependent on water, we find a loss in hair proportional to the time spent in the water The hair is quite efficient in regulating radiation

of heat from the body in mammals which seek water only for a short time Inasmuch as water is a better conductor of heat than air, the need for a more efficient heat retaining mechanism is obvious This is even more apparent in arctic mammals which have forsaken the land for an aquatic life In these a thick layer of fat beneath the skin subserves the function of hair in terrestrial forms

The huge size attained by many aquatic mammals tends toward overspecialization Such colossal size is found only in those species which have become completely emancipated from the land Howell[2] believes the gigantic elephant seal, which may exceed 20 feet in length, is now at the critical point as to size A slight increase either in its aquatic specialization or in its size might conceivably render it unable to spend even a short time upon land Then it must speedily adapt itself to an entirely aquatic existence or perish

The changes which have taken place in the organization of water living mammals vary in direct ratio to the time during which the influence of the water has been operating In other words, the changes will be greater or less according as a longer or shorter time has elapsed since the animals in question exchanged the terrestrial for the aquatic life[3]

hall being immovable and the lens spherical, having much thickened sclera and lacking the power of accommodation[4] Beneath the skin a specialized blubber layer minimizes radiation of heat from the body and dispenses with the need of a hairy covering The internal features of cetaceans are modified in keeping with the aquatic medium in which they live Teeth, when present, are homodont and conical in form, admirably adapted for grasping the slippery fish on which cetaceans feed The whalebone whales, lacking teeth, are equipped with baleen, cornified plates attached to the roof of the mouth (Fig 30) The inner border of these plates, through a process of wear, becomes brush like, to form an effectual strainer for the krill, crustacean and other small invertebrates, on which these gigantic creatures feed

The whales have need of a foreshortened neck, but this reduction has not been accomplished at the expense of the cabalistic number seven Instead, the cervical vertebrae are reduced to wafer like thickness, in some instances becoming ankylosed This brevity of the neck has modified the relations of balance between the head and trunk

The respiratory system of cetaceans has undergone extreme modification The lungs of the porpoise have a cartilaginous armature which gives unusual strength and incompressibility The smaller bronchioles possess muscular sphincter valves and other notable features, such as a complete lining of flattened respiratory epithelium instead of a partial one as in other known mammals[5] These sphincters are thought to close at the end of inspiration and ordinarily remain so until exhalation begins, preventing the gradual collapse of the air spaces as outside pressure increases, thus acting in antagonism to the elastic tissue of the lung Although these sphincters are weak, there are probably several million of them, imprisoning a minute amount of air, so that all of them working together are doubtless capable of preventing the escape of air even into the trachea under any pressure to which the animal is subjected[6]

Inasmuch as some whales descend to depths where they experience an external pressure in excess of a ton to the square inch, it is of paramount importance that external and internal pressure be equalized; this is probably accomplished in the manner outlined above

Sirenia. The manatees are scarcely less aquatic than the whales and their allies. Sea cows and manatees are quite incapable of a terrestrial existence, even for a short time. These animals live along coastal rivers and bays, often ascending to the headwaters. The fore limbs are paddle-shaped, with the digits enclosed in a continuous fold of skin, and are more mobile than those of the cetaceans. External hind limbs are absent, the tail forming an efficient swimming organ because of its vertical flattening and horizontal expansion. The rugose skin is essentially hairless. The nostrils open on the top of the truncated snout, the eyes are small, and an external ear is absent. The skeletal framework is dense and heavy. The apocryphal manatee (*Trichechus*) has but six cervical vertebrae and these are much compressed, resulting in an apparent neckless creature The single young is born in the water and raised out of the water by the mother at 3- or 4-minute intervals for a week after its birth, thus enabling it to get a sufficient amount of air.[7] The naked rugose coat and thick blubber layer of the manatee cannot be particularly effective in retaining the body heat, for numbers are killed in Florida during prolonged cold spells, when the temperature of the water they inhabit becomes lowered.

the almost hairless walrus and the thin haired earless seals

The form of all pinnipeds is remarkably streamlined, with a reduction of such external features as might hamper the movements of an aquatic species Thus the tail is reduced to a mere stump or vestige and the ears, when present, are very small The teeth of seals are peculiarly adapted for grasping and holding slippery prey (Fig 28) The enormous canines of the walrus, phenomenally enlarged in the males, are an aid in securing the mollusks which these great beasts scrape from the bottom of the shallow arctic seas Of the three groups, the hair seals appear to be best adapted for an aquatic existence

Other Aquatic Mammals The most aquatic American mammal, other than those previously discussed, is the sea otter (*Enhydra*) The greater part of its life is spent at sea, only occasionally hauling on the rocks or shore to rest It has been stated that the young are born at sea, in beds of kelp The sea otter is modified externally for such a pelagic life by large, well webbed hind feet, extremely dense and soft fur (the most valued of all North American fur), a slight vertical flattening of the tail, and small ears Internal modifications include a slightly foreshortened neck and an increase in the flexibility of the vertebral column [8]

The land otter (*Lutra*) has short legs, the hind feet well webbed, and a long sinuous body, to which is added a stout cylindrical, tapering tail The mink has a soft dense fur and hind feet which are slightly webbed, but scarcely more so than the weasel

Among American rodents, the most aquatic is the beaver, of which the underfur is extremely dense and the hind feet are large and well webbed The tail is naked, broad, and much flattened and occasionally used as a sculling organ, but swimming is usually accomplished by alternate strokes of the hind feet The muskrat is a small model of the beaver, except that its tail is flattened laterally A stiff fringe of hairs on the

outer edge of the broadly webbed hind feet is an aid in swimming

Water shrews (*Neosorex*) do not spend an appreciable time in the water, but when they are called upon to swim the stiff hairs which line the toes are an asset The star nosed mole (*Condylura*) is an adept swimmer, often resorting to the water for its food Unlike its near kin, this mole has a long tail which is used as a sculling organ when the animal repairs to the sluggish streams and ponds for food

The water opossum (*Chironectes*) of Panama is the only aquatic marsupial Its modifications for the water appear to be wholly confined to the broadly webbed hind feet

Little or no apparent modification is to be found in some species which spend much time in the water Notable among these is the polar bear, which differs from its strictly terrestrial relatives only in the hairiness of the soles and the more slender build, hardly an appreciable advantage for such a water lover The marsh and swamp rabbits of our Southern states often take to the water and swim easily and swiftly They have no peculiarities of structure which would stamp them as aquatic, if anything, they appear less adapted for an aquatic adventure than the Northern cottontail In fact, all mammals swim easily, at least for short distances Certainly the caribou and other members of the deer tribe present no specialized swimming equipment, yet they can, and do, successfully navigate wide rivers and lakes

BURROWING MAMMALS

Of the many fossorial mammals few have adopted a life of subterranean seclusion Among American mammals, the moles and pocket gophers alone spend their life underground, rarely venturing from their dark chambers The prairie dogs, ground squirrels, woodchucks, mountain beavers, and kangaroo rats are all accomplished diggers, but come forth from their burrows into the broader physical environment to secure food

Such semi-fossorial species require few modifications and retain the usual characters which are found among their kin which do little digging

External Modifications of Burrowing Mammals A consideration of the external features of the mole will serve to show the modification of characters associated with a fossorial life The body is more or less fusiform, with a long, pointed snout The eye is much reduced—indeed the eyelids are sealed in one mole (*Scalopus*)—although it may be seen as a small black speck in *Condylura* All the elements of the mammalian eye are present, but they are in such a crowded condition, owing to the great reduction in the size of the eyeball, that it would be impossible for them to function in a similar manner [1] The eyes of the pocket gopher are small, weak, and near-sighted Well-developed lachrymal glands are an obvious asset to the gopher, which needs the cleansing fluid to clear the eye of dirt

External ears tend to disappear, for they would impede burrowing to a marked degree, inasmuch as they are located at a point where much friction would occur In the mole a small ring of cartilage represents the auricle, and in the pocket gophers this structure is scarcely larger

The limbs are invariably short and stout, inasmuch as their function is that of a digger, with a corresponding sacrifice for speed The broad palmate fore feet of the moles, with their strong claws and auxiliary sesamoid structure, may be likened to broad shovels which throw the dirt to one side with incredible ease The long strong claws of the gopher are unusually efficient in loosening dirt In addition to this the sharp incisors of this animal, which are practically outside the mouth cavity, are a further aid in tearing loose the rootlets and soil Contrasted with these stout fore limbs, the pes is little modified, although stiff hairs or slight webbing may be present and provide a greater surface for throwing back the loose earth The tail of fossorial species is usually short and may have a sensitive tip Since the pocket gopher is able to

travel almost as swiftly in reverse as forward the value of such a sensitive tail tip is of importance

The lateral situation of the nostrils in some moles likewise appears provident, for there is less likelihood of dirt occluding the nostrils

The velvety pelage of the mole is short, dense and capable of lying forward almost as perfectly as the hair of other mammals lies backward, offering very little resistance to the animal s passage through the burrow The bair of the pocket gopher is scarcely less soft This appears to he a prerequisite of mammals which spend a large share of their time below ground We see it in the pine mouse in which tbe fur approaches the velvety texture of the mole but not in its less subterranean cousin the field mouse

Althougb sight is greatly reduced or lacking and hearing probably not acute, the other senses are magnified to an extreme The sense of smell is notably developed in pocket gophers and the organs of touch are acute The snout of the mole is equipped with thousands of nerve endings which make it a very sensitive tactile organ Moreover, the special ized hairs which partly encircle the manus are thought by some to function as sensory receptors thus adding to the prominent modifications which make the mole so successful as a subterranean dweller

Internal Modifications Profound changes have occurred in the skeleton of burrowing mammals far more marked than the external appearance would suggest Inasmuch as the animal s chief function is to dig, its main strength is con centrated in the fore part of the body In the mole, the whole pectoral girdle is pushed forward owing to the enormous development of the manubrium and presternum (Fig 40) This latter structure is greatly elongated and provided with a prominent ventral keel which gives a broad surface for the origin of the enormous pectoral muscles The pushing forward of the pectoral elements almost to the base of the neck gives the mole the appearance of being neckless The elements of

the fore limb are short, heavy, and equipped with numerous tuberosities which allow for attachment of the hypertrophied digging muscles. The heavy humerus of the mole, greatly changed from that of typical terrestrial mammals, would be scarcely recognized were it isolated from its connections.

The pelvic region of truly fossorial mammals is likewise modified, but here a reduction and fusion of the bones obtain. Inasmuch as the hind limbs function merely to push the animal through the earth or to throw back accumulated dirt,

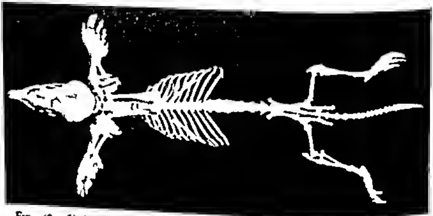

FIG. 40.—Skeleton of a mole, *Parascalops breweri*. This skeleton illustrates the extreme in fossorial specialization. The arrow-shaped skull with narrow zygomatic arches, the massive structure of the forelimb, the cylindrical thoracic basket, and the narrow pelvis are all impressive stamps of a subterranean life.

they must be firmly attached to the sacrum. The ilium is usually long and fused throughout its entire length to the vertebral column in the mole. The pubic symphysis is often lacking in both moles and pocket gophers, while the dorsal spines of the sacrum fuse to form a median dorsal crest; this and the ankylosed condition of the long ridges between the sacral elements and the pelvic bones provide additional strength. The narrowed pelvis resulting from such fusion allows the mole to turn on itself in the narrow confines of its tunnel. The great reduction in the pelvic outlet allows no room for the passage of the urogenital and alimentary tracts,

awkwardly about on the ground and swims well, is seldom seen other than in trees, where its pendulous body is suspended by enormously developed hooked claws The number of dorsolumbar vertebrae are often increased, in the two-toed sloth, these vertebrae number 27 In the three-toed sloth, the dorsolumbar vertebrae are of the typical 19, but an addition of the neck vertebrae from the customary seven to nine allows for a mobile neck The anteater (*Cyclopes*) is strictly arboreal, possessing a long prehensile tail, with powerful flexor muscles and very efficient grasping feet The hind limbs and tail act as a tripod on which the animal stands erect, bowing and swaying from its leafy lookout in evident play.

The New World monkeys are extraordinarily gifted for life in the trees The wonderful delicacy of the hand, the long limbs, and the slender sensitive tail, serving for grasping or as a balancing organ, are impressive stamps of an arboreal life (Fig 39) The facility with which these monkeys dash recklessly from limb to limb is amazing and is graphically summarized by Chapman[11] who writes of the white-faced monkey (*Cebus*) in this fashion

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blubber, or a thick layer of fat, weapons to dig or paw through the snow, and a color that matches the environment are features which make arctic existence possible

Inasmuch as all mammals, irrespective of their bulk, give off an equal amount of heat per unit of surface, it is an advantage for arctic species to decrease their body surface Since volume and mass increase as the cube of the linear dimensions and surface only as the square, a more considerable body size serves to reduce the heat radiation [11] The same or related

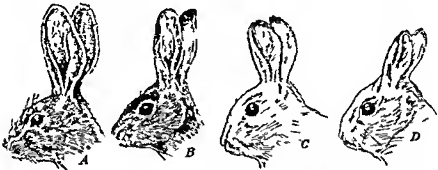


Fig 41 —Arctic mammals tend to be larger than their kin of more southern latitudes Since all mammals give off an equal amount of heat per unit of surface it is to the advantage of northern species to reduce as much as possible their external surface This situation is reflected in a smaller size of the ears and tail The ears (*A*) of an Arizona jack rabbit (*Lepus alleni*) are tremendous These are much reduced (*B*) in a jack rabbit (*Lepus californicus*) from Oregon The varying hare (*Lepus americanus*) from northern Minnesota has still smaller ears (*C*) while the smallest ears (*D*) of all are found in the arctic hares (*Lepus arcticus*) of the Barren Grounds

species tend to attain a greater body size in colder regions than in more temperate latitudes, at the same time reducing the surface area of such external features as the ear and tail This may be observed in the ear length of the hare (*Lepus*) In the hares (*Lepus alleni*) of Southwestern United States the ear is tremendous, attaining 23 7 per cent of the total length of the animal In the California jack rabbit it is reduced to 20 7 per cent, while in Washington, Oregon, and the Great Plains it reaches only 19 3 per cent of the total length The varying hare of Northern United States and

Canada has an ear length which is 13.5 per cent of the total length, while the arctic hare of the barren grounds has a yet smaller ear, approximating 12 per cent of the whole length of the animal (Fig. 41). The ears of various foxes illustrate the same point. The huge pointed ears of the desert fox are in marked contrast to the much smaller ears of the red fox of temperate America. The arctic fox has small rounded ears, reducing in this manner the surface of the body available for the radiation of heat.

In Northern Greenland, where deep snows cover the creeping willows, saxifrages, and other edibles during the greater

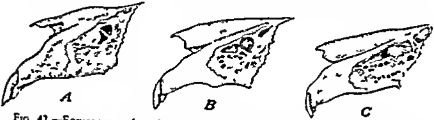


FIG. 42.—Environmental modifications in the incisor teeth of hares. The long protruding teeth (*A*) of the Greenland Hare (*Lepus groenlandicus*) are of great assistance in picking away crusted snow and reaching the covered mosses and stunted willows. Such extreme development (*B*) is not found in the arctic hare (*L. arcticus*) for much of its food grows above the snow. The incisors (*C*) of the California jack rabbit (*L. californicus*) are not modified in this manner for its food is easily secured.

part of the year, the arctic hares have responded to this environment by developing extraordinarily long, obliquely projecting incisors, which act as tweezers in extracting from beneath the snow the tiny plants on which they depend (Fig. 42). The snow is usually easily removed by the heavy black claws and prognathous teeth, but when a crust forms difficulty is experienced. At such times the food plants are located by smell, and the crust is broken by hammering with the fore limbs. When the crust is well broken over the area, the icy covering is removed by means of the teeth.[18] The mammals of arctic America which dig through the snow for food are all provided with stout claws or capable hoofs. The hares have long black blunt claws, much stouter than

their Southern relatives The lemming (*Lemmus*) has claws not unlike other small rodents during the summer months With the approach of snow, a bulbous portion grows on the underside of the two middle fore claws, finally attaining a size greater than the normal claw The claw then appears not unlike two claws, one underneath the other The highly modified fore claws undoubtedly serve as an aid in digging through the closely packed snow With the disappearance of the snow and a cessation of subnivean activity the auxiliary claw is lost The barren ground caribou likewise has much broader hoofs than its relative of the forests A noticeable feature of the Peary caribou is the large size and length of the hoofs and the developmeots of the dew claws ioto regular spoons as large as a hare s ears, thus giving the caribou natural snowshoes, which they need in Northern Grant Land not only for the snow, but for the boggy saturated ground of early summer [13]

As the arctic winter approaches all herbivores and many of the flesh eaters have acquired a considerable store of fat The caribou has a prominent layer of back fat, deposited from the shoulders to the rump, which may attain a thickness of 3 inches or more and equal a sixth of the weight of a mature buck in prime condition This fat not only acts as a reservoir of stored up food but serves as a splendid insulation, retaining the body heat of the animal to a remarkable degree The winter carcasses of northern weasels which the writer has examined have all been provided with prominent strips of fat over the belly, the inguinal region, and, to a lesser extent, the rump It is not unlikely that all terrestrial species acquire this before the advent of cold weather

Aquatic mammals of boreal regions must develop a thick layer of subcutaneous fat to inoculate them against the cold The hair seals and walrus lacking a dense coat of fur, are like the arctic whales, equipped with a thick layer of fat It has been stated that two fifths of a seal s weight is com posed of hide and fat Fat is a very effective thermal insulator

for a seal causes no visible melting after remaining for hours on an ice floe, a dead walrus retains a high body temperature even after 12 hours of submersion in ice-cold water [14]

Reindeer and musk-ox are said to seek quiet localities and crowd tightly together The exhaled and transpired moisture of the herd forms a cloud above the animals, beneath which the warmed air is retained as if in a closed room [15]

FIG 43—The musk-ox (*Ovibos*) of arctic America is well adapted for life in the far north Woolly coats 18 inches long in places provide an adequate insulation against months of subzero weather

We may observe yet another phenomenon characteristic of northern mammals, particularly well developed in arctic species Reference is made to the periodic molt which results in a change from a dark summer pelage to a white winter coat It is pronounced in the arctic hares, weasels, wolves, foxes, and certain caribou and is even apparent in the lemming (*Dicrostonyx*), which spends the greater part of its time in

subnivean activity Indeed, certain species, as the hares of Ellesmere Island, the polar bear, and, to a lesser extent, the Peary caribou, retain their pristine pelage at all seasons Not only does this white coat act as a concealing coloration, making both predators and their prey relatively invisible against the snow, but it serves an even more useful purpose The light or white coloration of many arctic species supposedly radiates much less heat than a dark pelage would and this is of much greater moment than the absorption of the minute heat which reaches them from the sun during the long arctic winter

In arctic mammals the coat is much denser than in those of temperate latitudes The soles of the feet are furred in the polar bear, hares, foxes, and lemmings The polar hares possess dense woolly fur, while the coats of the larger herbivores are even more strikingly developed The new hair of the arctic caribou is at first fine and flexible but gradually increases in diameter at its roots As winter advances, the thickness of the hairs at their base becomes so great that they are exceedingly close, and cannot lie down smoothly but stand erect [16] The deep dense wool of the musk-ox, covering the entire body, is overlaid by long coarse flowing hairs (Fig 43) This hair hangs from the animal in a great robe, some 20 inches long in places, and forms a protecting mantle that is effective in shedding the rain and snow of the hostile land where it dwells The thick underwool forms a substantial blanket which retains the body heat to a remarkable degree, thus insuring the desired insulation from arctic blasts

DESERT MAMMALS

Source of Water Supply In the great desert areas of the West are to be found many groups of mammals peculiar to these dry, hot, and barren regions There has been much speculation as to how such animals obtain moisture in a country where there is no open water and where there is often no rain, snow, or dew for months or even years at a time It appears

patent that some species have never learned to drink yet they maintain healthy bodies with an abundance of internal fluids and well filled bladders The studies of the production of metabolic water by Babcock[1] has shown that carbohydrates fats and protein may be chemically converted into 50 to 100 per cent of their weight of water by oxidation or molecular change within the cells of the body, thus supplying much of the water necessary for vital processes Mammals must eliminate their waste in the form of liquid urea Although few desert mammals actually secure enough water to drink they have found a permanent supply of choice foods with a high water content

A typical example is the antelope jack rabbit (*Lepus alleni*) Vernon Bailey has observed that these big desert hares live on dry valley slopes and mesas where for long distances no water is available where open water does occur the jack rabbits do not go near it even in times of long drought Their principal source of water is the pulpy leaves of cactus particularly the prickly pear (*Opuntia engelmanni*) which is the most abundant and least spiny cactus in the district where these rabbits are found At least 78 per cent of the pads of this cactus are water The viznaga (*Echinocactus wislizeni*) is another favorite and its juicy flesh may exceed 94 per cent water The jack rabbits commonly dig up tubers of several fleshy rooted plants which show by desiccation that they have a 70 per cent water content The droppings of desert rabbits are almost dry and the urine is thick and scanty so that there is evidently little loss of moisture from the bodies and a constant accumulation of it from the fleshy cactus and underground tubers which abound in these arid regions

The kangaroo rats (*Dipodomys merriami*) live in the hottest dryest part of the United States Their principal foods are various seeds but they dig avidly for the little juicy tubers of *Portulaca* that grow abundantly over the desert and are usually to be found an inch or so below the ground level The buds and sprouts of small composite bushes, comparable to fresh

crisp head lettuce, are eagerly sought by these little desert rodents [18] Many of these desert mammals, when kept in captivity for long periods, never touch water if a supply of green food is kept on hand Pocket mice (*Perognathus*), ground squirrels, grasshopper mice, and pocket gophers all occupy the desert region, many living by choice or necessity in very dry or barren regions, and all must procure their water requirements from the moisture stored in the desert plants

Small species are unable to endure the heat of the surface of the desert These dig burrows, thus reaching a zone where temperature and humidity are nearly constant The kangaroo rats, spiny pocket mice, and ground squirrels may close the mouth of the burrow with a plug of earth during the day, this undoubtedly stabilizes still further the climatic conditions which prevail within their earth retreat Many, if not all, of the small desert mammals of Western America are totally nocturnal, indeed they could not live more than hour or two in the extreme heat of midday Larger forms, as the jack rabbits, remain in the shade of mesquite, cactus, or a chaparral thicket and when alarmed soon return to the life-saving shade which the scant vegetation affords

The long droughts and paucity of rainfall which are characteristic of deserts result in a meager flora, which flowers and seeds in a remarkably short period The little desert rodents dependent on these seeds must be equipped to harvest such concentrated food in a relatively brief period, before the seeds become wind blown and widely scattered They are admirably fitted for such a task, provided as they are with capacious cheek pouches It is probable that a kangaroo rat can harvest in a single night food sufficient for a long period In semi-deserts, where the desiccating winds of early summer destroy all green vegetation, the small mammals meet such adverse conditions by a long aestivation or hibernation, repairing to their underground chamber during July and not emerging until late winter

Many desert rodents are saltatorial The bipedal movements of the little kangaroo rat are a result of its extremely long hind limbs, admirably adapted to leaping, while the fore limbs are atrophied, serving only in limited fashion as propulsive organs Its long tail and elongated hind limbs, plus a fusion of the neck vertebrae, tend to restore the center of equilibrium, which might otherwise be destroyed by the enormous head and capacious, well filled cheek pouches Here we find a parallelism with the whales, which tend to become heady and whose equilibrium center is likewise restored not by a reduction of the cervical vertebrae but by a fusion of the bones This results in an apparent absence of a neck and the fusion of the enormous head directly to the trunk The saltatorial habit of many small desert rodents may be due to their need of erratic movements to escape predators in a habitat notably lacking in escape cover

BIBLIOGRAPHY

1) Howell A Brazier 1930 Aquatic Mammals Springfield Ill p 48
2) Howell *op cit* p 47
3) Kukenthal W 1891 *Ann and Mag Nat Hist* 154
4) Kellogg Remington 1928 *Quart Rev Biol* 3 195–198
5) Wislocki George B 1929 *Amer Jour Anat* 44 64–66
6) Howell *op cit* p 316
7) Barbour Thomas 1937 *Jour Mammalogy* 18 107
8) Howell *op cit* p 31
9) Slonaker James R 1902 *Jour Comp Neur* 12 354
10) Chapman Frank M 1929 My Tropical Air castle New York p 285
11) Hesse Richard W C Allee and Karl P Schmidt 1937 Ecological Animal Geography Chicago p 386
12) Manniche A L V 1910 *Meddelelser om Grønland* 45 1 200
13) Peary Robert E 1907 Nearest the Pole New York p 205
14) Hesse Allee and Schmidt *op cit* p 385
15) Hesse Allee and Schmidt *op cit* p 512
16) Richardson John 1829 Fauna Borealis Americana London p 242
17) Babcock S M 1912 *Univ Wis Agr Exp Sta Res Bull* 22
18) Bailey Vernon 1923 *Scientific Monthly* 17 66–86

CHAPTER V

FOOD

Largely because of economic considerations, the food habits of American mammals have been much studied. Although the dietary habits of mammals have not been so well catalogued as those of birds, nevertheless we possess a fair picture of the foods regularly taken by the larger species and of those small forms which have significant interest to the agriculturist. In spite of all these data, the food habits of a great many species are but imperfectly known. The food of any one species may vary from day to day, as it surely does with the seasons. Moreover, most animals have individual preferences. This fact is well indicated in the apparent contradictory findings of many scientists who have studied the food habits of a given species. Intra specific predilections of food are just as pronounced as are other habits.

Availability. Availability largely determines the nature of the food eaten by mammals. A rather striking illustration of this is afforded by the dietary habits of red squirrels on the Cornell University campus. On the lower campus, the large elms provide an abundance of swelling buds in the early spring, and these are eagerly consumed by the squirrels. The sprouting seeds of soft maple are also dug from the lawn at this season. As the elm seeds ripen, the squirrels sever the branch tips and repair to the ground to feed on their loot. By early May the ripe seeds have formed windrows along the walks and are effectually stored in the cracks and crevices

that border these walks The seeds thus provide food for the squirrels through the summer and fall As snow covers the ground, the squirrels gather this still abundant food and harvest the acorns from a few large oaks They thus rely chiefly upon the elms for their food supply

Scarcely 200 yards away, their kin living in the wooded gorge slopes rely upon an entirely different food Here hemlock and pine abound, the annual crop of cones providing a dependable source of food during the lean months The flowers and seeds of box elder and striped maple ensure a food supply in the spring Berries, mushrooms, and the succulent roots of a variety of annual herbs tide them through the summer In brief, it seems probable that some of these squirrels have never known the joys of the elms with their annual crop of millions of seeds

Cabot[1] states that in Labrador bears, wolves, foxes, wolverines, birds of prey, and trout became numerous with the increase of mice As these rodents suddenly disappeared, the wolves commenced to harass the caribou, birds of prey became scarce, the bears resorted to berries, and the foxes stalked ptarmigan The mouse decline had a profound effect on the native population, reducing the game and fur animals

The chief food of the prairie dog is grass and herbaceous plants but Whitehead* gives a good illustration of their adaptive behavior During the fall of 1923 great swarms of grasshoppers were observed in the Panhandle section of Texas One of the swarms in passing over and alighting in a prairie-dog town provided a great feast for the animals The prairie dogs were out in full force chasing after, catching, and eating the grasshoppers Numbers of the animals were successful in fielding the low flying and dropping grasshoppers as they passed Some of the rodents in making the catches jumped into the air

Our most successful and abundant species are adaptable changing their aliment when a favorite food becomes scarce Thus we find foxes stalking the ubiquitous field mouse at

every opportunity There comes a time when deep snows preclude the possibility of the fox s catching these mice in sufficient quantities to appease its wants It may then prey on the hard pressed pheasant or dig through the snow covered orchard for frozen apples If these and other nutritious foods be lacking, the fox may repair to wind swept fields of winter wheat and fill its stomach with the green blades

Changing Food Habits In northeastern forests, Hosley[3] has observed that during periods of deep snow, when the red squirrel s usual food supply is cut off, it eats the buds of certain coniferous trees, the normal growth of which is thereby retarded The terminal and lateral buds of Scotch and white pine, Norway spruce, and larch are clipped off The damage has been observed only in recent years, which suggests that the lack of pine seed and hardwood mast for winter storing, which are less abundant in the present young, cutover forests of light seeded species, has been the cause of this change Moreover, the chestnut has completely disappeared as a source of food

Specialized Feeders Some mammals lack this adaptability and, in the absence of specialized foods, soon starve The red tree mouse (*Phenacomys longicaudus*) lives among the evergreen forests of the Pacific Coast Most of its life is spent in the Douglas firs, where its nests are made, in close association with abundant food supply Although the mouse is not highly specialized in structure it is exceedingly so in food habits The normal food apparently consists largely, if not solely, of the fleshy parts of the needles and the bark from the tenderest growth of the twigs of fir trees[4] It has been noted that captive mice ate freely of many substances other than fir needles,[5] but if deprived of these needles the mice died in a short time When feeding on fir needles, the mice were observed to eat the medullary portion of the needle, discarding the sides and resin ducts

The anteaters of tropical America subsist almost entirely on various species of ants The anteater is remarkably adapted

for this specialized diet Its long mouth appears as a mere tube through which is projected a long and sticky tongue capable of drawing hundreds of ants from their fortress (Fig 44) Enders[6] writing of *Tamandua* says

This tongue is truly a remarkable instrument for it is capable of following a tunnel to its end then passing over to a parallel tunnel the tip may clear it

Fig 44—The edentulous giant anteater (*Myrmecophaga centralis*) has a tubular snout and long viscid tongue Thus it is well adapted to feed on ants and termites which appear to be its chief food The tongue can follow the tortuous galleries of ants and gather these insects with ease

out by moving in the opposite direction from the base This was observed on several occasions while holding dead branches and termite ridden papaya leaves from which an anteater was feeding

The anteater is further provided with strong powerful claws with which it tears apart the termite hills and logs which harbor ants

The sloth (*Bradypus*) is said to feed chiefly upon the leaves of the cecropia, although in captivity it may be induced to take less palatable food

We may gain some impression of an animal s food by an examination of its dentition, but this is by no means an in fallible procedure We are accustomed to consider the car nivores as meat eaters, while the rodents supposedly find their food in the plant kingdom Everyday observation tells us that such a premise is not true Many mammals are om nivorous The black bear has a formidable dentition, adapted for a flesh diet, but its food consists largely of roots, berries and fruits, and grubs and other insects Practically all our mice are flesh eaters and insectivorous, the well named little grasshopper mouse of our Western states feeding on scorpions grasshoppers, and other insects

Utilization of Food If one should contrast the utilization of food made by a largely herbivorous species and that by a species which is truly carnivorous, a significant difference would be immediately apparent Contrast the feeding behavior of a squirrel or deer with that of a bobcat The former two species nibble a bit here, sample a taste there, and move on The bobcat eats every vestige of its kill or, becoming surfeited before its victim is entirely consumed, hides it away for another feast The red squirrels will feed on the fallen heads of maple seeds in the fall During the severe weather they resort to stored cones and nuts but yield to the dormant buds of many trees Maple buds are avidly eaten in February, elm buds in March and the flowers of these and many others as they blossom Twig cutting commences as the blossoms go to seed, and the ground will often be covered with the terminal tips of limbs, only a few blossoms or seeds of which have been removed These lavish feeding habits are notable, but they have a certain significance as Nichols[7] has stressed

Whatever crop the squirrels are enjoying at a given time, be it acorns, seeds, buds, is at that particular time far in excess of their needs It behooves them not so much to con

serve their food as to cultivate a varied appetite and wide knowledge of what is good to eat and where to find it, so that failure of any source at any particular time of year or in any particular year will not find them at a loss as to where else to turn for sustenance

MARSUPIALIA (Opossums)

American opossums are omnivorous creatures, feeding as they do on fruits, berries, worms, snails, and insects and other invertebrates The Virginia opossum has an extremely varied diet A North Carolina specimen which the writer examined had eaten a newly hatched box turtle, several centipedes, and a score of wasps Another found dead on a New York highway had last eaten a small garter snake, a quantity of grasshoppers, and several wild cherries Indeed, this species is probably as omnivorous as any flesh eater

The little murine opossums (Fig 12), scarcely larger than a rat, feed on fruits and insects They search the banana plantations for small animal life and are frequently brought to the United States from Central American ports as banana stowaways

Water opossums (*Chironectes*) appear to feed chiefly upon crustacea Inasmuch as they chiefly haunt the waterways of Panama it is suspected that they eat any moisture loving invertebrate that they may come upon

INSECTIVORA (Moles and Shrews)

As the name of the order implies, moles and shrews feed in large measure upon insects and other small creatures The strenuous life of the mole produces a huge appetite and these creatures feed avidly at all opportunities

Many investigators have studied the food habits of the mole All have been in essential agreement that the diet of these animals consists chiefly of animal matter, including earthworms, grubs, beetles, wireworms, millipedes, centipedes, and other small animals of the soil In a study con

ducted by Hisaw[8] on the food of captive moles (*Scalopus aquaticus machrinoides*) it was found that soaked corn was eaten readily The animals also fed on certain seeds and vegetables when there was an overabundance of insects and worms

The big Townsend mole of the West Coast relies chiefly upon the earthworm although Wight[9] adds insect larvae and pupae, centipedes slugs, and vegetable matter to the food Vegetable food may form an important addition to the mole s menu, as Moore[10] observed in Oregon More than 50 per cent of the moles examined by Moore had taken vegetable matter some of the stomachs being filled solely with the remains of bulbs, while vegetable fibers, roots, and grasses occupied a considerable portion of the contents

The star nosed mole (*Condylura*) is found in a variety of habitats, but it delights in the soft black muck of the swamp or borders of slowly flowing meadow streams Less specialized than its relatives it can push through the mud with greater facility Here it finds an abundance of worms and the larvae of aquatic insects The star nosed mole is an accomplished swimmer often diving to the stream bed, where it seeks the smaller crustacea and it has been known to eat small fish [11] It may share the large muskrat house with the rightful tenants, building a nest in the wall from which it forages to the near by water The long tail is adapted to its needs and acts as a sculling organ while the mole is swimming

The amount of food eaten by moles is truly prodigious Brooks[12] noted that a Brewer s mole in the space of 24 hours ate more than its own weight of food Hisaw is inclined to discredit such a colossal appetite but reports moles kept by him ate from one-third to two thirds their weight in a single day Moles are reported to draw earthworms through the back of the paws, in this way freeing the digestive tract of earth before devouring the worms The writer has observed captive specimens do this but the procedure is by no means a universal practice

If a mole encounters a live insect in its burrow, it immediately slams it against the side of the burrow with one of its big front paws and holds it while at the same time it turns its head to examine the catch If the prey is not crushed with the first blow, it is repeatedly mauled with the big paws and bitten or held against the side of the burrow while its body is being devoured piecemeal The attack is vicious and executed with incredible quickness and agility The mole also captures active prey by piling loose earth on a victim and devours it while holding it in this way This clever method handicaps captives by compelling them to scramble from beneath loose soil and it may even succeed in smothering them [13]

The small nature of the food of shrews has rendered its identification difficult but it is known in a general way that these tiny mammals subsist chiefly on insects annelids mollusks and the other insignificant life of the leaf mold

Scientists who have placed live mice in cages occupied by captive shrews have observed that the shrews invariably overcome and devour the mice with much celerity and dispatch A number of writers have suggested that these little flesh eaters must take a sizable toll of the mouse population and this suggestion seems further strengthened when we take into account the mutilated bodies found in the traps of the collector Nevertheless the results of detailed stomach analysis of the larger shrews does not bear out the contention that they are confirmed mouse eaters and we must be forced to believe that they add such substantial food to their menu only when they blunder onto a nest of young mice or successfully trap one in an underground passage

The water shrew (*Sorex palustris*) and marsh shrew (*Sorex bendirii*) are modified for a partial aquatic existence and have been known to catch small fish They also feed upon water snails although their food habits do not appear to differ essentially from those of their close relatives These shrews may locally be called fish mice because of their aquatic tendencies A friend of the writer was once troubled with

some small predator which continually pilfered the trout eggs from trays sunk in flowing water Baiting a weighted mouse trap with these eggs he was rewarded by catching several water shrews Svihla[14] remarks that a captive water shrew quickly swam to the bottom of an aquarium where it literally stood on its long flexible nose which was thrust into the sand and debris searching for food its feet kicking rapidly in order to maintain this position The length of time it remained submerged varied from a few seconds to a quarter of a minute Frequent diving made up for the short periods of submergence

All shrews are moderately fond of snails Shull[15] made some interesting observations on the food of the big short tailed shrew (*Blarina*) He noted that these shrews prey upon various snails of the genus *Polygyra* at least in winter The snails are hoarded by the shrews and are moved to the surface of the ground as the temperature falls and into the burrows as the temperature rises Empty shells are brought to the surface and not moved again into the burrow One often finds little piles of snail shells the whorls eaten away and the contents neatly removed in the numerous runways that thread through the leaf mold and under rotten logs Probably most of this work may be attributed to various shrews although mice are known to eat snails

Shrews have been credited with a savage disposition turning upon their own kind the stronger soon killing and devouring the weaker The oft-quoted experiment of Merriam[16] is known to many He confined three small shrews (*Sorex cinereus*) beneath a tumbler and the shrews immediately commenced fighting In a few minutes one was slaughtered and eaten by the two others Before night one of these killed and ate its only surviving companion Hence in less than 8 hours one of these tiny wild beasts had attacked overcome and ravenously consumed two of its own species each as large and heavy as itself These shrews weigh not more than a penny! The writer has kept a number of shrews all of which

have lived in perfect harmony with their own kind if well fed Moreover, abundant field evidence suggests sociable dispositions not in accord with the savage nature accorded these little beasts by several naturalists

Shrews have ravenous appetites and must eat often and fully Specimens taken in traps invariably show well filled stomachs, and captives deprived of food for a few hours become weak They are known to succumb, possibly from starvation, if deprived of food a short time On the other hand, the writer has had the big *Blarina* fast for a full day and, except for a noticeable constriction in the abdominal region, it appeared as lively as well fed neighbors A water shrew collected by Svihla[1] showed no ill effects from a 2-day abstinence from food

CHIROPTERA (Bats)

The food of our common American bats consists almost entirely of flying insects, most of which are taken on the wing No bird can match the aerial gymnastics of the bat as with quick turns and evolutions it soars throughout the twilight in quest of food Many insects are caught with the jaws, the snapping teeth of the bat being distinctly heard if the observer is near Others are trapped by the tail membrane and picked out by the sharp teeth If the insect is too large to be mastered while the bat is in flight, the bat repairs to a nearby tree Here the body, dropped wings, and interfemoral membrane are used to form a pocket or pouch and the insect is readily killed by a bite or two in the head [18]

Bats may alight on the ground to secure food Hatt[19] found the Pacific pallid bat (*Antrozus pacificus*) feeding on scorpions and Jerusalem crickets, both of which are incapable of flight

The Seminole red bat is known to feed on the flightless crickets,[20] and the California leaf nosed bat is suspected of seeking food on the ground since one has been captured in a mouse trap set on the open ground

Our small northern bats have limited feeding grounds, many species seeming to prefer a small area, two or three large trees or the restricted shore line of a small pond. Here they circle back and forth until their stomachs bulge with a multi-

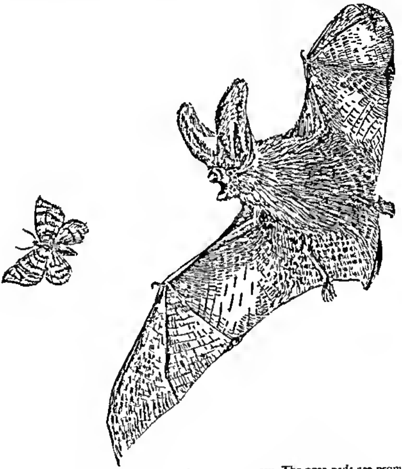


FIG. 45.—A big-eared bat (*Corynorhinus*) pursues its prey. The nose pads are prominent in this genus. Note the curled tail membrane with which some bats capture their flying prey.

tude of insects, when they repair to some favorite retreat to digest the meal. In the extensive caves of the Southwest, such as Carlsbad, the vast numbers must fly several miles to enjoy a profitable hunt. Observations made by Nelson[21] in Mexico

indicate it to be a common habit for certain bats to fly a number of miles from their roosts to their feeding grounds every evening During summer evenings at San Antonio, Texas, soon after sundown it is customary to see great numbers of the free tailed bat flying over the town, practically all headed in one direction

The exact nature of the insects eaten by bats is difficult of determination, for the sharp teeth thoroughly masticate the prey, leaving only finely comminuted chitinous fragments as a clue A study of several thousand fecal pellets of the big brown bat (*Eptesicus*) made by the writer indicates that slow flying beetles, flying ants, braconids, ichneumons, muscid flies stoneflies, mayflies, a few hemipterous insects, caddis flies and a few orthopterous species occurred in that order of abundance Both injurious and beneficial insects were recognized, suggesting that insectivorous bats are most useful in their general warfare against the tribe of insects, rather than for the control of any specific noxious species (Fig 45) We might add here that, in spite of much which has been written to the contrary,[12] the presence of large numbers of bats in no case appears to have the slightest influence on the prevalence of malaria

By no means is the diet of bats restricted to insects The largest of the bats, or flying foxes, found in the tropical countries of the Old World feed on the pulp of fruit Tropical America can boast of a number of small fruit bats which feed on the soft pulpy fruit of bananas and mangoes The writer has shot large fruit bats (*Artibeus jamaicensis parvipes*) in Cuba as they repaired to bunches of ripening bananas in the early evening This species may occasionally occur in Florida

The big fish-eating bat (*Noctilio*) of the tropics has excited much attention These swift flyers are found in Mexico Panama, and several islands of the West Indies The bats live in caves, occasionally coming out in the bright sunshine to feed in company with the pelicans or wing their ghostly way through the darkness swooping over the water Chap-

man[23] actually saw this large pale bat, about the size of a nighthawk, which it resembled in flight, course to and fro low over the water From time to time it dragged the surface of the water for a distance of several yards with its spread interfemoral membrane, producing a soft swishing sound The bats may actually catch fish with their strong feet Stomach analyses prove the fish-eating propensities of this rank smelling bat but also indicate its fondness for mole crickets, ants beetles, and other insects [24] Another fish eater *Pizonyx* occurs on the islands and coast of the Gulf of California where it hides during the day under stones heaped up by the waves and among the porous lava rocks of the steep hillside The enlarged feet and claws, the relative freedom of the leg from the wing membrane and the elongated tooth cusps suggest a diet consisting at least partly of fish and this supposition has been confirmed by Burt [25] who found the stomachs of these bats distended with fish remains

Some of our tropical bats have marked carnivorous habits The big spear nosed bat (*Phyllostomus hastatus*) has been studied in captivity by Dunn,[26] who observed the species to capture and devour quantities of lesser bats mice, and birds It has been concluded from this that these bats seek a flesh diet under natural conditions The big Asiatic *Megaderma lyra* habitually preys on small birds, mice and frogs Green[27] has called attention to this fact relating how the veranda of his home in Ceylon has been strewn with bird and mouse remains morning after morning while other observers have actually witnessed these great bats feeding on their hapless victims

The sanguivorous nature of the vampire bats (*Desmodus*) has long been known to travelers in the American tropics These bats range from Mexico through Central America to the warmer parts of South America Vampires are small bats well fortified with very sharp strong caniniform incisors for cutting through the skin of their host The wounds are said to be similar to those caused by a razor when shaving a

large number of severed capillaries being thus exposed, from which source the blood is drawn, through the exceedingly narrow gullet.

The vampire does not suck the blood, according to Dunn,[?] but takes it up with its tongue, seldom placing its mouth on the wound. If the wound bleeds freely, the bat simply laps up the blood, hardly touching the tissues, while if the bleeding is scant the bat licks the wound. The vampire possesses a very powerful anti-coagulant to blood It is said that small wounds made by the sharp teeth of these bats may bleed freely for two or three days, but the statement needs confirmation This bat is a vector of paralytic rabies, a disease which has become alarmingly common in parts of South America and which is 100 per cent fatal. The bat also carries the germs of murrina, Chagas' disease, and trypanosomiasis

CARNIVORA (Bears, Raccoons, Weasels, Foxes, Cats, etc.)

The flesh eaters, so called, show a remarkable diversity in their food habits Some species feed for prolonged periods chiefly on fruits and berries (foxes, raccoons, bears) while others are truly carnivorous, restricting their choice of foods largely to meat (weasels, minks). This order includes some of our most adaptable feeders, many species being able to change their diet with little inconvenience, if a particular food fails

Bears Bears are found throughout North America and wherever they occur are omnivorous The black bear feeds on insects and their larvae, honey, berries, succulent roots, and most mice and other small mammals and rarely becomes destructive to livestock, killing pigs, lambs, and calves The writer has observed a black bear in northern Maine feeding on the fruit of mountain holly (*Nemopanthus*) and blueberries, stripping them from the bushes with its teeth. The excreta at that time consisted almost wholly of the seeds and skins of blueberry Black bears will straddle small shad bush trees (*Amelanchier*), forcing the tree over until the ripening berries

are secured Bailey[29] watched bears strip the fruit from cascara trees, the berries of which appeared to have a strong purgative effect on the bear The same writer[30] noted that black bears in the mountain region of New Mexico were feeding upon manzanita berries, acorns, black cherries, pine nuts and juniper berries When the acorn and pine-nut crop had proved a failure, the bears had gone in pursuit of bearberry (*Arctostaphylos uva ursi*), rose haws, grass and other green vegetation, and insects

Raccoons and Their Allies The raccoon, like its close relative the bear, is omnivorous, feeding on a variety of foods Mice, earthworms, birds, fruit, grains, frogs, fish, insects, and crustacea all contribute to its sustenance When streams are low, the adept raccoon will pull fish from the shallows with its hand like paws or search the stream border for crayfish It digs up and eats the eggs of turtles in the summer, repairing to the beech woods in the fall for abundant mast Dearborn[33] has carefully examined about 500 raccoon feces taken in Michigan during the summer The most important item, crayfish, constituted 59 per cent of the food, while grain fruits, insects, mammals, and mollusks and other lesser creatures made up the remainder The fall and winter food of the raccoon in New York State is indicated by Fig 46 The raccoon by no means invariably washes its food before consumption, as has often been erroneously stated Indeed, much of the food is taken in places rather far removed from water

Grinnell and Storer[31] observe that the ring tailed cat subsists largely on mice and other small rodents Small birds and fruits are also an important food They add to these the following berries madrone, manzanita, cascara, yew, black berries, huckleberries, and also acorns squirrels, wood rats and birds (chiefly varied thrushes)

The coatimundi (*Nasua*), like the raccoon, is an omnivorous feeder, taking insects and their larvae, rodents, fruits, and reptiles The coati is an accomplished climber and undoubt

edly destroys large numbers of birds. It has been seen to stalk iguanas.[32] The arboreal kinkajou (*Potos*) is frugivorous, consuming quantities of tropical fruits, but it is also known to eat insects. The related ring-tail cat (*Bassariscus*) is widely distributed in the Southwestern United States, north along the coast to Oregon This handsome beast feeds upon small rodents, wood rats, and even bats Nelson[33] states that

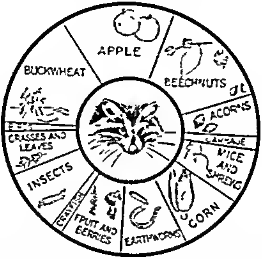


FIG 46—The diet of the raccoon during the fall and winter months is illustrated in this chart The stomachs of animals killed in New York during the hunting season were examined by the author, and the results are shown in the diagram. The food of a species may vary from one season to the next, or from year to year, depending upon what is available and most easily secured

insects of many kinds, larvae, and centipedes are eaten, as well as a great variety of fruits, including that of the pear-leaved cactus, dates, figs, and green corn.

The Weasel Tribe. The Mustelidae include a large number of genera and species, ranging in size from the least weasel, no larger than a chipmunk, to the 35-pound wolverine In keeping with this disparity in size, the food may consist of a cricket or a full-grown deer. Many are highly insectivorous and a few decidedly frugivorous

The weasels (*Mustela* spp) feed chiefly upon small mammals, although an occasional bird may be eaten Abbott[34] made a splendid contribution to our knowledge of the food of weasels About his home in New Jersey, he watched a family of weasels through a summer and fall and was impressed with the large number of rats the parents brought to their young Late in the fall he found about their dens the remains of grasshoppers, crickets, frogs, and mice Those who have found the home dens of weasels list various species of mice frogs, and an occasional bird We learn of the good services of the smaller weasels (*M rixosa*) through Criddle,[35] who states that the winter quarters of 27 vole communities, each harboring four or five mice, were all entered by weasels, the inhabitants having been killed and partly eaten Furthermore, these small weasels had made the homes temporary centers from which they raided other rodent habitations in the vicinity The larger weasels (*Mustela frenata*) kill quantities of rabbits and in the West are said to prey upon ground squirrels, pikas, and pocket gophers Earthworms form a supplementary food for weasels when other food is scarce Osgood[36] watched a pair of weasels (*Mustela cicognani*) carry many worms to their young Numerous traps set in the meadows surrounding the nest indicated that mice had been entirely eliminated for some distance about the den

From the foregoing account *it is* hard to believe that weasels are bloodsuckers alone, an accusation that has repeatedly been leveled at them Nevertheless, they all delight in blood, as observations of Leopold[37] suggest Leopold observed a weasel strike a young cottontail rabbit with incredible swiftness while on the run and without any pause continue out of sight into the dense brush The rabbit squealed, collapsed, and lay kicking, a small patch of blood showing at the base of the skull The weasel soon returned to lap the blood from the wound

Weasels have devised a highly successful manner of procuring and killing their catch A rapid dash and the luckless

mouse is grabbed over the back of the skull, the fore legs encircle the prey as though hugging it, while the hind legs are brought up to scratch wildly at the captive Thus the predator is free from unlikely attacks and may securely hold the victim, if the grip must be loosened or changed for one at a better vantage point

The food of the mink (*Mustela vison*) is not unlike that of weasels but it is more given to fish Dearborn[38] has reported on the summer food of the mink in Michigan, the greater share of the food consisting of crayfish, next in order were small mammals, frogs, fish, and insects Muskrats are eagerly sought by the mink, and the writer has found much evidence of their depredations on this large rodent when opening muskrat houses in the winter Stomach analyses do not tell the whole story "A marauding mink was shot while pursuing captive wild ducks and its stomach disclosed, not ducks, but a small garter snake and a mass of fur of the Norway rat"[39] The western mink has been seen hunting the tidal pools for small marine life, and it is known to open successfully and eat clams[40]

Mink frequently enter poultry houses and destroy quantities of chickens, killing far more than enough to suit their wants This carnal lust is more pronounced than in the weasel During severe weather, mink, being great wanderers, often temporarily desert the watercourses and repair to the hills, where they pursue and destroy many rabbits

The marten (*Martes americana* and related species) makes its home in the coniferous forests of the North It weighs perhaps 2 or 3 pounds, and is largely arboreal The food list is a long one, in which Seton[41] includes partridge, small birds and their eggs, rabbits, squirrels, chipmunks, mice, shrews, frogs, fish insects, nuts, berries, honey, and carrion The last he thinks the principal food, although it is well established that the marten is usually absent where there is a lack of tree squirrels It pursues and overcomes the nimble footed red squirrel with

ease. Several writers have attested to its fondness for the berries of mountain ash. Its constant residence in the rock slides of the Yosemite led Grinnell and Storer[42] to suspect that its chief food must consist of the smaller conies and bushy tailed wood rats.

The fisher (*Martes pennanti*) has a varied diet but feeds principally on hares, mice, squirrels, and lesser forms. It is an avowed enemy of the porcupine, killing great numbers and being not in the least dismayed by the formidable armature which clothes these animals. The quills which are ingested pass through the alimentary canal without in any way disturbing the sensitive lining. Although the chief food of the fisher consists of mice, squirrels, and other small fry, it is known to kill fox and raccoon and even successfully to attack the deer. It is said to catch and feed upon its smaller cousin, the marten.

The wolverine (*Gulo*) is the strongest of the mustelids, being able to overcome a caribou. There is a record of its killing a moose.

The dietary habits of the skunk (*Mephitis*) have been studied more fully than that of any other mustelid, and we are now well informed on the food, which includes a long list. During the summer skunks feed chiefly upon insects, fruits, and small mammals. As cold weather approaches, they add grasses, leaves, buds, grains and nuts, carrion, worms, and such other matter as they can readily find.[43] The skunk is not an epicure. It eats almost any edible upon which it happens. Its chief reliance appears to be insects, for droppings examined in the summer and fall months almost invariably contain fragments of beetles, grasshoppers, and crickets and chitinous pieces from other insects. Skunks are adept at locating and digging out the nests of snapping turtles (Fig. 90), field mice, and bees. The last possess a special charm for their mephitic enemies, as many an apiarist will confess. Well over half of the food of 1,700 skunks examined by Dearborn[44] consisted

of insects, chiefly grasshoppers, crickets, and beetles, while fruit, grain, and small mammals made up the better share of the remainder

Skunk stomachs examined by Bailey[45] in Texas were mostly filled with beetles, grubs and grasshoppers, ripe cactus fruit, persimmons and berries, crayfish, and pocket mice Dixon[46] studied a large number of California skunks and concludes that these animals subsist largely on small mammals and insects, chief among which are gophers, ground squirrels, and Jerusalem crickets

The badger (*Taxidea*) feeds principally upon small rodents Dearborn[47] found that 96 8 per cent of the food of Michigan badgers consisted of field mice and their allies, rabbits, ground squirrels, and deer mice Squirrels, insects, and turtle eggs made up the remainder In the lake and marsh country of Iowa, Errington[48] found the remains of striped ground squirrels, meadow mice, insects, feathers of grebe, teal, and pheasant and eggshell particles As in Dearborn s studies, the principal food was ground squirrels and mice Bailey[49] states that in Texas the badgers feed mainly upon small rodents such as pocket gophers, kangaroo rats, wood rats, and various mice, with grasshoppers, beetles, scorpions, and lizards, but further claims the principal food to be prairie dogs and ground squirrels

The land otters (*Lutra*) are essentially acquatic, procuring the majority of their prey from lakes, streams, and rivers Stomachs which the writer has examined have invariably contained coarse fish (suckers) and quantities of crayfish Other than these items, little specific information is available on their food Otters are known to kill wild fowl

The sea otters (*Enhydra*) are able to spend the greater part of their time in the water, where all their food is procured Early writers have listed crabs, clams, and other forms of bivalves and crustaceans as forming their principal diet Small fish, sea urchins, and squids are eaten[50] The nature of the molar teeth, which have rounded, crushing surfaces, would

indicate their use in crushing shells rather than catching and tearing the flesh of fish Extensive study of sea-otter food on the Commander Islands in Bering Sea by Barabash Nikiforov[51] discloses that sea urchins, mollusks, crabs, fish, and seaweeds are the chief food The animal, which habitually swims on its back, belly up, holds its food on its chest and uses its fore paws while feeding Williams[52] has confirmed these reports, finding essentially the same food in sea otters of the Aleutians

Coyotes, Wolves, and Foxes The various wild dogs and their kin exhibit a wide choice in their food selection, changing and adapting their tastes with the seasons and the availability of food

The red fox (*Vulpes fulva*) feeds largely upon mice, rabbits, and fruits but will take birds, carrion, insects, and such other food as it may happen on The writer has studied the food habits of this species for a number of years in Northeastern United States and concludes that the summer food consists primarily of small mammals, fruits and berries, birds, insects, and reptiles[53] Along the Atlantic Coast foxes find and devour sea birds and their eggs, fish, and other food washed up on the beach They are fond of blueberries, serviceberries, and the fruit of wild sarsaparilla, wild cherries, blackberries, and other such edibles Foxes dig up and eat the eggs of several species of turtles During the winter they dig through the snow for frozen apples, grains, and nuts and what carrion they may obtain Foxes occasionally kill fawns, lambs, and pigs and are known to attack successfully the skunk and porcupine They persistently hunt house cats and kill quite a number Dearborn[54] observed quantities of insects in the feces of Michigan red foxes

The food of the gray fox (*Urocyon*) does not differ essentially from that of the red Among the foods of Virginia gray foxes listed by Nelson[55] we find rabbits, field mice, deer mice, wood rats, numerous passerine birds, spotted turtles, insects, centipedes, apples, beechnuts, corn, peanuts, grapes, hickory nuts, persimmons, and carrion Stomach analyses of a dozen

gray foxes examined by the writer show these animals to eat rabbits, muskrats, field mice, robins, pheasants, rum cherries, beechnut, and sweet corn in the milk. Grinnell, Dixon, and Linsdale[56] found the California gray fox feeding on jack rabbits, mice, pocket gophers, wood rats, ground squirrels, tree squirrels, insects, wild berries and cultivated fruit, small birds, and carrion Gray foxes visited an orchard, climbed peach trees, and shook the fruit to the ground, where the young animals were waiting to feed on the fallen peaches The gray fox is an accomplished climber and does not hesitate to ascend trees in New Mexico for juniper berries and piñon nuts[57]

We have little actual knowledge of the specific feeding habits of the kit fox (*Vulpes macrotis*), but analogy would suggest a dietary not unlike that of his larger cousin, the gray fox Inasmuch as the range of kit foxes corresponds closely to that of the large kangaroo rat, Bailey[58] believes this to be one of their favorite varieties of game. This suspicion has been confirmed,[59] for about the den of a California kit fox were found the tails of kangaroo rats, ground squirrels, feathers, a snake, beetles, and grasshoppers.

In summarizing the food of the arctic fox (*Alopex*) Seton[60] gives first place to the ubiquitous lemming but adds ptarmigan, arctic hares, sea birds, nesting wild fowl, seal pups and seal placentas, and fish Often several will follow the great polar bear, picking what crumbs he leaves at bis table in the form of discarded seal flesh.

The coyote, like others of its tribe, feeds freely on what ever the country may offer. Its important economic status has received much attention and the consequent thousands of stomachs which have been examined now provide us with much testimony on the food The coyote feeds on practically all animal life it can master, subsists for long periods on carrion, and disdains not a berry or fruit Seton[61] records currants, rose seeds, sarsaparilla, mice, fish, waterbeetles, grasshoppers, and ants Stock and game (much of it carrion), rodents,

mammals, wild and cultivated fruits, insects, and birds were found in California coyotes by Dixon[62] The winter food habits of 1,697 coyotes collected from ten Western states has been summarized by Sperry,[63] who lists carrion, rabbits, and rodents as the important foods, those playing a lesser role including sheep, deer, birds, and vegetable matter

Keller[64] noted that, while snow lay deep on the ground, a Utah coyote had killed and eaten two porcupines in less than 3 hours Coyotes are said to destroy many foxes in Alaska, chasing these animals from their dens, killing them, and utilizing the den for their immediate needs[65] A number of coyote feces from northern Michigan which the writer examined contained evidence of varying hares, deer, muskrats field mice, and grasses Coyotes undoubtedly kill large numbers of calves, sheep, and poultry At times the food of the coyote consists largely of fruit, including cactus, juniper berries, persimmons, and the sugary pods of mesquite[66]

The food of wolves is not unlike that of coyotes, hut being considerably larger animals they must prey on bigger game Beside the mice, rabbits, ground squirrels, and other small fry, they successfully bring down steers, horses and other livestock, deer, carihou, and even moose

The Cat Tribe Our native cats are more strictly carnivorous than any of the meat eaters thus treated hut they also make an occasional meal of fruits and herries

The wild cat (*Lynx rufus*) feeds chiefly on small mammals, rabbits, and hirds More than 300 feces from Michigan were studied by Dearborn,[67] who concluded that the varying hare was the most important food, comprising 89 per cent of the food Remains of deer, muskrat, mice, squirrels, and hirds were also found in the droppings A study of Vermont boh cats made hy the writer[68] discloses the food of these cats to consist primarily of carrion, deer, mice, rabbits, porcupine, squirrel, grouse, skunk, shrews, muskrats, and blue jays, with an occasional fox, chicken, grass, fish, and insect Small mammals appear to constitute its chief food in the West

Fig 47 —Capybaras and jaguar The capybara is the largest existing rodent Specimens may attain a weight of 80 pounds

Naturalists have recorded a preponderance of wood rats, rabbits, and various mice, although Dickey[69] found six Western robins in the stomach of a California specimen The bobcat is known to kill and eat house cats

The Canada lynx relies chiefly upon the rabbit millions of the North When these disappear, as they periodically do, death from starvation stalks the lynx This is well reflected in the close correlation between the snowshoe-hare population and the number of lynx skins which reach the fur markets Other foods, listed by Taylor and Shaw[70] and based on the study of excreta, show that the animals feed upon different kinds of rodents, such as chipmunks, lemming mice, white-footed mice, jumping mice, red-backed mice, meadow mice, and mountain beavers Lynx are known to feed on grouse and ptarmigan and abundant evidence shows them to be remorseless enemies of the red fox

The mountain lion is a huge cat, weighing 80 to 150 pounds or even more They are typical western animals but at one time were abundant in the East, even yet occurring in the fastness of southern Florida swamps Their chief food is deer (Fig 92), it has often been reliably reported that they kill at least one of these animals a week, and there are records of one lion's killing seven deer in ten days Other food of the cougar includes small rodents, mountain beaver, porcupines, skunks, and marmots At least one person has met death at the hands of these big cats, and numerous records, some based on authentic data, show further unprovoked attacks on humans

The jaguar and ocelot of tropical America do not differ in their food habits from their Northern cousins The jaguar is said to kill the tapir but undoubtedly relies upon the capybara (Fig 47), agoutis, and peccaries, herds of the last being followed and the stragglers disposed of with ease It has further been noted to comb the beaches in the turtle season, feeding on such delicacies as the eggs of sea turtles The

ocelot relies upon spiny rats, opossums, other small mammals and such birds and their eggs as it may find

PINNIPEDIA (Seals and Walruses)

Seals The food habits of the California sea lion have been carefully investigated by Dyche,[71] who found squid remains and large octopuses in the stomachs of a considerable number Fish were not evident in any of the stomachs nor feces examined although rock cod were abundant and caught in numbers about the rookeries that had been used by the sea lions for ages

Sizable stones are often found in the stomachs of sea lions sealers explaining that the seals swallow them for ballast when they leave the breeding grounds The stones may act as triturating agents, as no effort is made by the seals to masticate their slippery food

Merriam[72] examined the stomach contents of a large number of fur seals and found the great bulk of their food to consist of squids, hundreds of whose beaks were found in the stomachs, while in only a few instances were any traces of fish discovered Fur seals taken in the spring off the coast of Washington contained squids herring shrimps and lampreys [73]

The elephant seal feeds at great depths Huey[74] has examined the stomach contents of a large male and records rat fish, sharks skates, and squids, some of which are customarily found in from 300 to 720 feet of water It is thus evident that the seal must descend to such depths in pursuit of its food, and this fact is further supported by the deep water in which the animal was captured 40 miles from the California shore This deep-diving habit would also seem to be aided by the seal s very large eyes, which would be of decided advantage in the dimly lighted waters at any depth over 100 feet

The food of the western harbor seal (*Phoca richardii*) has been studied by Scheffer and Sperry [75] Analyses indicate that

fish are the usual food, those taken most frequently being tomcod, flounders, herring, hake, sculpins, cod, pollack, and shiners Squids, octopus, and crustacea contribute slightly to the piscivorous diet A few stomachs of the Atlantic harbor seal taken in the summer mouths have been examined by Griffin,[6] who found only fish remains (menhaden and alewives)

Walrus The walrus feeds on clams, sea snails, and other mollusks of the kind which frequent sand banks in shallow water These are rooted out of the sand by the aid of the powerful tusks and swallowed entire, with a stone or two for good measure The shells pass through the body in the natural way and are discharged on the rookeries, largely in an unbroken state It is therefore necessary that the herd should have a large area to dig over, as such enormous animals must require a large amount of food[7] Sutton[8] remarks that the walrus feeds principally upon mollusks, although he found few shells in the stomachs Allen[9] quotes Malmgren as stating that the walrus of Spitzbergen subsist almost exclusively upon two species of mollusks, which live buried 3 to 7 inches deep in the mud, in 60 to 300 feet of water In securing their food, these huge beasts sink down to the sea bottom in a sloping direction until they almost stand on their heads, they then move backward, ploughing the bottom with their tusks, after a short time they return to the surface to breathe and then again go down[10]

RODENTIA (Squirrels Rats and Mice Gophers Beavers Porcupines etc.)

Rodents as a group can hardly be classed as vegetarians, feeding as they do on a miscellany of insects, fish, amphibia birds, and other mammals, besides their usual fare of plant life Indeed it is safe to state that in some instances, where suitable and abundant insect life occurs, some species will forego their usual fare of vegetation for prolonged periods seemingly preferring the rich harvest of grasshoppers, ground

beetles, and other terrestrial invertebrates which often occur in abundance Many rodents are adept at bird catching, and not a few delight to dine on their lesser kin Strict vegetarians are few The porcupine is one, and we doubt not that it would and does dine on insects when opportunity affords The

FIG 48 —Red squirrel and spruce cones Both the red and pine squirrels commence to harvest cones while these are yet green and store them in the damp earth Did they wait for the coniferous seeds to ripen these would soon be wind blown and lost to the squirrels Cones are sometimes recovered and eaten two years after they have been buried by the harvester

beaver is essentially a strict vegetarian, but few more can be listed which restrict themselves to bark, grasses, and fruit

Sciuridae (Tree Squirrels, Chipmunks, Prairie Dogs, Wood chucks, etc) Tree squirrels feed upon bark, leaves, most fruits, berries, fungi, insects, and birds and other animal life disdaining scarcely any food which they happen on The red squirrel (*Tamiasciurus*) is a species typical of the northern coniferous forests subsisting upon the cones of various pines

and spruces The cones are often removed long before the seeds have been scattered by the wind (Fig 48) The winter buds of many conifers are devoured As spring approaches, red squirrels tap maple trees and avidly drink the sap or nibble on the sweet icicles formed by the flow A wide variety of berries is consumed, the face and alimentary tract often being stained from such gluttonous repasts Red squirrels eat many species of fungi, the poisonous amanitas being relished and eaten without apparent harm [81] This species is known to be destructive to birds, not infrequently robbing the nests of eggs and young Red squirrels have been known to kill and eat the young of cottontails and gray squirrels [82]

Gray squirrels have similar feeding habits but appear more dependent upon mast one of their most important foods being the hickory [83] Like its red cousin, the gray squirrel takes eggs and the young of birds when opportunity affords and eats a wide variety of insects This species often consumes the bark of various hardwoods and may do considerable damage to trees This bark-eating trait appears to be more pronounced in England where the gray squirrel has become well established The handsome tuft-eared squirrels (*Sciurus aberti*) occasionally do serious damage to ponderosa pines by stripping bark from the limbs They also consume quantities of pine seeds, eat seedlings, and destroy the eggs and nestlings of birds [84] The food of the fox squirrel does not differ in any essential degree from that of its gray cousin

Flying squirrels (*Glaucomys*) appear to feed chiefly upon nuts, berries, and seeds and occasionally do some damage to pecan groves [85] These squirrels are very fond of insects and are frequently attracted to lights at night, probably knowing they will find a ready feast of moths and other night flying creatures

Ground squirrels (*Citellus*) feed chiefly upon green vegetation early in the season, later resorting to seeds and stems of grasses, many species of insects, and various fruits and berries A Texas antelope squirrel (*Ammospermophilus*)

had fed for a considerable time on the fruits of cactus, which had tinted its flesh purple throughout [86]

The striped ground squirrels of Colorado often feed upon grasshoppers and other injurious insects to the exclusion of all other food [87] They likewise exhibit a fondness for white grubs, and large numbers have been found in the stomachs of several Michigan specimens which were examined [88]

Both the eastern chipmunk (*Tamias*) and its western relative (*Eutamias*) feed on nuts, grains, wild fruits and berries fungi, snails, slugs, insects, birds, reptiles, and small animal life generally Chipmunks are inordinately fond of berries and make regular trips to a thicket of blackberries or raspberries when these are in fruit The little sage chipmunk (*Eutamias minimus pictus*) has been known to feed extensively upon the larvae and pupae of a webworm that was stripping the sagebrush Several stomachs examined contained little else but these insects, and it was estimated that the caterpillars formed about 60 per cent of the chipmunk food at that time [89] Chipmunks have been known to capture and devour snakes, salamanders, and frogs A chipmunk has been seen to dash upon a group of house sparrows, bite one mortally, and drag it to a hole [90] Another has been observed carrying a large field mouse, which indicates an occasional penchant for a meat diet on the part of this rodent [91]

Woodchucks subsist largely on vegetable matter, delighting in clover, alfalfa, plantain, and other succulent greens They feed on buds and the flower heads of many herbaceous plants and do not disdain an occasional diet of flesh Grasshoppers, snails, and small birds have been recorded in their dietary, while their ability to climb trees, searching out berries and small fruits, has not gone unnoticed So far as we know, the woodchuck is more strictly herbivorous than his near relatives, the prairie dogs and smaller ground squirrels

Geomyidae (Pocket Gophers) The underground habits of pocket gophers account largely for their vegetarian diet which includes a wide variety of succulent roots, grasses

bulbs, and tubers They not infrequently girdle fruit and other trees The pocket gophers of Texas feed on yucca, sotol cactus, and agave [92] The prairie pocket gopher is reported to feed extensively upon all broad leaved plants, particularly those of the pea family [93] It is also fond of flesh but shows little indication of being insectivorous, even though the burrows may harbor many kinds of beetles, flies, and camel crickets

Heteromyidae (Kangaroo Rats, Pocket Rats, etc) Pocket mice, kangaroo mice and rats, and their relatives are essentially desert or plains animals and as such feed chiefly upon seeds Many species live in arid regions, seldom having access to water The pocket mouse (*Perognathus*) is said to be a strict vegetarian, its natural food consisting chiefly of the seeds and grains that it can harvest from native plants, supplemented by the green stuff available in the semi arid country at certain seasons [94] The kangaroo rats of Southwestern United States rely principally upon forage plants, chief among which are various species of grama grass (*Bouteloua*) The food stores are composed primarily of seeds [95] Mesquite beans and needle grass are stored in some quantity for winter use

Castoridae (Beavers) The beaver is a typical vegetarian, subsisting almost entirely on the bark of trees, grasses, and herbaceous plants Aspen, cottonwood, willow, birch, and other deciduous trees furnish abundant bark The bark of conifers is seldom, if ever, eaten, although hemlock and pines are often utilized in the construction of the dams and lodges The summer season finds them feeding on marsh grasses, roots of aquatic plants, and, to a lesser extent, fruits and berries The writer has watched beavers consuming quantities of green algae during July There is little evidence that beavers participate in a meat diet, nor are they known to be fond of flesh, such as fish or clams

Cricetidae (Native Rats and Mice) Among this large and dissimilar group we find many species with diverse food habits, but all are essentially omnivorous, although they are for the most adapted to a vegetable existence The little grass

hopper or scorpion mice (*Onychomys*) of our Western plains usually feed on a great variety of arthropods, including grasshoppers, crickets, scorpions, mole crickets, beetles, caterpillars, cutworms, and insect eggs They also eat the flesh of many small mammals which they kill, occasional lizards (Fig 49), and many weed seeds [96] A captive grass hopper mouse ate, in a forenoon, 16 crickets, 11 grasshoppers, 1 spider, 1 black bug and 1 big fly Harvest mice (*Reithro-*

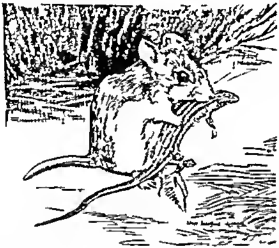


Fig 49—Contrary to general belief rodents are not entirely herbivorous Indeed some feed almost exclusively on insects when these are abundant The little grasshopper mouse (*Onychomys*) captures scorpions and even masters lizards which it eats with relish

dontomys) are not so insectivorous, subsisting largely on the seeds of grasses and the succulent stems of these plants

The widely distributed deer mice (*Peromyscus*) rely chiefly upon seeds, grains, small nuts, and dry vegetable matter During the summer quantities of berries are consumed, and caterpillars, beetles, centipedes, snails, and even flesh of their own kind are eaten with relish During the fall these mice are partial to beechnuts, basswood, maple, wild cherry, and viburnum seeds, many of which are stored for winter use Deer mice often collect the cocoons of the luna moth, storing them in some convenient shelter until such time as the con

tents are to be utilized as food They collect the wind-blown seeds of conifers or extract these from the fallen cones Great stores of clover seed are cached by *Peromyscus* for winter use The writer has recently examined several score of eastern deer mouse stomachs, and the analyses indicate a decided predilection for insects, small mammals, and birds

In the Carlsbad Cave of New Mexico, Vernon Bailey found these mice feeding principally upon the large crickets found in all parts of the cavern In North Dakota Bailey found these mice had stored in one cache the seeds of chokecherry, wood bine, wild grape, smilax, buffalo berry, hosackia, dogwood, bindweed, knotweed, pigweed, ragweed, Russian thistle, black henbane, sedge, barnyard grass, and dropseed grass From this long list one may reason that the deer mice are not selective but take practically any seed which is available in sufficient quantity

The rice rat (*Oryzomys*) eats a variety of seeds, sedges, insects, fruits and berries, nuts, and any small animal life it may happen on It takes the large seeds of the gama grass, wild rye, the seeds of marsh grass (*Spartina*) and, these failing, it retires to the shore for food, where it finds an abundant harvest of small crustacea and mollusks which are exposed at low tide Their larger relative, the cotton rat (*Sigmodon*) has similar food habits, but in addition has proved a menace to ground nesting birds, feeding on the eggs and young of quail and other avian species

The big wood or pack rats (*Neotoma*) are chiefly vegetarians About their nests in the rock ledges of the Allegheny Mountains one may find the buds, terminal twigs of many oaks birches, and hickories, the flower heads, fruit, and berries of a wide assortment of herbaceous plants, fungi, snails, nuts, and similar food items The writer has found fresh cuttings of spurge, red cedar, locust, primrose, phlox, and redbud back in the caves inhabited by these rats A food study of the dusky-footed wood rat in Oregon indicates a preference for apple, maple seeds, crabapple, snowberry, willow, wild rose, Doug-

las fir, wild currant, oak, acorns, bracken fern, and many other flowers, fruits, and bark [97] Desert wood rats eat seeds, berries, and cacti, while in the Northwest the species may even eat alder bark [98]

The short tailed voles are all essentially vegetarians, never appearing to consume such quantities of insects and other animal life as do the long tailed cricetine mice and rats

The lemming mouse (*Synaptomys*) confines its diet largely to grass stems and roots, its stomach usually containing a mass of finely chewed green vegetation Of the dozen or more lemming mice examined by the writer, only one had fragmentary insect remains in its alimentary tract The arctic lemmings (*Lemmus* and *Dicrostonyx*) utilize grasses, mosses lichens, and leaves Our knowledge of the food habits of the ground-dwelling *Phenacomys* is scanty, but these habits probably do not differ materially from those of its near relatives The peculiarly arboreal tree mouse (*Phenacomys longicauda*) has an extremely specialized diet, feeding as it does almost entirely on the needles of Douglas fir Furthermore, these mice have become adept at removing and discarding the sides of the needle and the resin ducts, eating the remainder of the leaf [99]

The red backed mouse feeds on the leaves and tender stems of many herbaceous plants and enjoys the nuts of many trees particularly those of the oaks, beech, chestnut, and hazel It has been stated that this little forest mouse seems fond of certain land snails and often resorts to the leaves of the ever green strawberry bush (*Euonymus americanus*) in winter [100] It may cause much injury to forest trees by severely girdling the roots and trunk, eating away great areas of bark The writer has seen this little mouse with a beechnut in each cheek and another between the teeth during the busy storage season of autumn

The ubiquitous meadow mouse (*Microtus*) occurs throughout practically the entire North American continent One species or another occupies every ecological niche, from the

dry plains region to the cold boreal mountain tops well above timberline Their food is thus varied but consists primarily of vegetation, especially the succulent green grasses and stems of herbaceous plants In winter, under a protecting mantle of snow, they find abundant dormant shoots and tubers Many species store food for use during the cold months The little bean mouse (*Microtus pennsylvanicus wahema*) of the arid plains country collects great stores of wild beans (*Falcata comosa*) the long tubers of artichoke (*Helianthus tuberosa*), and the little white tender roots of wild morning glory For ages the Plains Indians dug up these stores, which often contained a peck or more These stores formerly also provided a considerable portion of the sustenance of the Dakota Indians during the winter In return for robbing these little mice of the fruits of their labor, some of the more conscientious squaws placed corn or other food in the empty caches [101] In Eastern United States field mice feed chiefly upon the basal stalks of various grasses or cut the long stems in sections to reach the seed or flower heads Orchard grass, clover, and alfalfa are particularly relished, but a list of those plants which are often utilized by these little voles would fill many pages The bark of apple, wild cherry, maple, ash, Scotch pine, and many other trees and shrubs is eaten in the winter, and the resultant damage is often of considerable proportions when these mice are at all abundant They do not appear to relish meat so much as the pine mouse, for of many hundreds trapped by the writer, none have ever been disturbed by their kin Insects are seldom found in the stomachs, which usually are distended only with a mass of finely chewed, dark green vegetation

The subterranean habits of the pine mouse (*Pitymys*) account for its diet of succulent roots and tubers Young sprouts of white clover and the tuberous roots of the violet have been found in these underground storerooms [102] The tubers of Dutchman s breeches and squirrel corn are often stored for winter use, while the rootstalks of morning glory, quack grass, dock, witch grass, and sandbur are found in their

caches, captives never refuse meat when proffered [103] Stomach analyses of a number of pine mice made by the writer have often disclosed fragmentary insect remains

The aquatic muskrat (*Ondatra*) is an adaptable creature feeding on a host of water and land plants Where it occurs especially in the North, the cattail (*Typha*) is a plant of much importance to these animals, providing bedding and building material and a very considerable alimental need In the Eastern states, the summer food of this overgrown mouse includes burseed, many pondweeds (*Potamogeton*), arrowhead, various grasses, many species of sedge, duckweed, curly dock, smart weed, pond lilies, and clover, a host of leaves and tender twigs of shrubs and small trees are also consumed [104] In the Louisiana tidal marshes, where great numbers of muskrats (*Ondatra rivalicia*) live, the chief food plants appear to be the three square grasses (*Scirpus*), needle grasses (*Juncus*), and paille-fin grasses (*Panicum*, *Spartina*) [105] In California the muskrat is said to avail itself of the great quantities of water and wind borne seeds that are piled in little windrows at the water s edge [106] The muskrat does not disdain a meat diet and consumes great quantities of the big lake and river mussels The muskrat will venture far out on the ice of a sizable lake when ice cracks have formed, to dive through these cracks and shortly reappear with a mussel, which is eaten on the ice [107] Fish and dead birds have been included in its diet by several observers The writer has seen a muskrat feeding on a small freshly killed carp

Aplodontiidae (Mountain Beavers) The Aplodontia feeds on almost any available plant growing near its burrow The animal is thought to be active throughout the winter and hence must store quantities of vegetation for its use at that season In the Yosemite the mountain beaver was observed to utilize azalea (*Rhododendron occidentale*) extensively, while hazel, Sierran currant, creek dogwood wild cherry, snowbush, chinquapin, incense cedar, white fir, sugar pine, and brake fern were all used sparingly [108]

Zapodidae (Jumping Mice) The feeding habits of jumping mice do not differ essentially from those of the deer mouse. Unlike the latter, they hibernate, at least in the northern part of their range, so practice no storage. Stomach analyses have revealed large numbers of insects, both lepidopterous and coleopterous species, fruits of blackberry, seeds of small plants, and the starchy blanched shoots of succulent grasses.[109] One can often find the little crisscross piles of slender grass stems in the meadows, the work of *Zapus*, which has cut them to bring the seed heads within reach. The woodland species (*Napaeozapus*) appears to favor fruits, berries, and juicy insect larvae more than its cousin of the meadows. Both are attracted to the berry bushes during mid summer and gorge themselves from the earthen banquet table below the raspberry and blackberry bushes at this season.

Erithizonidae (Porcupines.) Taylor[110] has prepared an extensive list of the chief foods of the porcupine for different parts of the United States, including Alaska. Included in this list are pines (inner bark, leaves, etc., of western yellow pine, jack pine, piñon, limber pine, whitebark pine, foxtail pine, lodgepole pine, sugar pine, western white pine), western yellow pine mistletoe, tamarack, spruces, hemlocks, firs (Douglas fir, cork-bark fir, white fir), oaks (barks, acorns, twigs), birch, basswood, ash, cottonwood, poplar, aspen (rarely), alder, sugar maple, slippery elm, beechnut, willow, wild fruits (gooseberries, currants, plums, strawberries—leaves), chokeberry, buffalo berry, elder, black haw, rose bushes, raspberry cones, squaw bush, leaves and seeds of a knotweed (*Polygonum*), buckbrush (*Ceanothus spp.*), chinquapin, geranium, aster, parsley, lupine, cinquefoil, dandelion, and other weeds, plus a host of herbaceous species, apples and other fruits, vegetables, alfalfa, grain, and grass. In the Northeast the porcupine's chief article of diet during the winter is the hemlock, which is stripped of its foliage and twigs and from which the bark is removed in great areas on the trunk. During the summer it frequents the lake shore,

dining on the succulent stem and roots of arrowheads, pond plants, and other aquatics The porcupine appears to be especially attracted to the fleshy rhizomes and leaf pads of pond lilies [111]

LAGOMORPHA (Rabbits Hares and Pikas)

The rabbit tribe are vegetarians, including in their diet almost any acceptable plant and many which we human beings would think quite unpalatable to even a jack rabbit The cottontail (*Sylvilagus*) eats a variety of buds, twigs, grasses flowers, and weeds It delights in sweet clover, alfalfa, and the succulent stems, leaves, and flower heads of many herbaceous plants During the winter season the northern cottontails feed upon the bark and soft wood of staghorn sumac apple, sugar maple, beech, wild cherry, and ash, while the entire young shoots and small branches of raspberry and blackberry canes, basswood, red osier dogwood, slippery elm various dogwoods, oak sprouts, and such are avidly consumed The cottontail will dig deep into the snow to recover a few frozen apples If other food fails, it will turn to insects and has been found to tear open cocoons and eat the pupae of the large silk moth *Samia cecropia* [112] Several investigators have indicated that rabbits are fond of snails and often eat these mollusks

The varying hare (*Lepus americanus*) inhabits the Northern United States and Canada Its principal food is the succulent new shoots and tender twigs of many northern trees, but it may resort largely to the bark of poplar, willow, birch, and others in winter The snowshoe rabbit does not disdain meat and will often spoil the trap sets placed for valuable fur beaters, when these are baited with flesh [113] The great arctic hares (*Lepus arcticus*) are dependent for food upon the few dwarf plants that grow in the frozen regions where they make their home Chief among these are the creeping willows crowberry, and saxifrage, in the absence of these staples, the hares eat moss and withered grass [114] The big jack rabbits

(*Lepus alleni* and *L. californicus*) of our Western states feed extensively upon the leaves of perennial plants which spring up following the winter rains. During and May and June the grass dries up, and mesquite and several species of cactus (prickly pears, viznaga, chollas, hedgehog cactus, pincushion cactus, and others) are eaten.[115]

The little chief hare or pika gathers any available plants that occur about its rocky fastness (Fig. 53). Many species of grass, thistle, meadow rue, pea vine, heath, and the leaves of composite plants have been found in its hay pile.[116] A hay stack examined by Vernon Bailey in New Mexico contained 34 recognizable species of plants, the most common being nettles, chokecherry, gooseberry, currant, raspberry, rose, snowberry, syringa, lupine, and aspen. In some localities pikas seem to have a preference for the leaves of trees and shrubs.[117]

ARTIODACTYLA (Peccary, Antelope, Deer, Moose, Caribou, Bighorn, Bison, etc.)

The world of vegetation provides sustenance to the hoofed animals, few of these large species forsaking their diet of grass and browse. The deer tribe are, in general, browsing species, while the bovids (bison, sheep, antelope) secure the greater share of their food by grazing. One would be in error to make such a statement without qualification, many deer graze extensively upon grasses at certain seasons, and, moreover, the bison and antelope may feed extensively upon browse.

Tayassuidae (Peccaries). The peccary (*Pecari*), a small pig-like ungulate of our Southwestern border and Central America, is an omnivorous creature. In New Mexico it is said to rely chiefly upon the acorns of various oaks, pine nuts, juniper and manzanita berries, cactus fruits, and wild potatoes.[118] The Texas peccary feeds on fruits, seeds, and roots and grubs in the earth for worms, insects, reptiles, or bulbous roots; it is considered destructive to lizards, toads, and snakes.[119]

Cervidae All members of the deer tribe are delicate feeders, browsing as they move, snipping a tender twig or flower here and there The spring and summer months provide them with abundant lush vegetation, leafy shrubs, and annual plants, but during the Northern winter they often band together in yards, feeding at this season on bark, twigs, and the needles of conifers

The wapiti (*Cervus canadensis*) is considered by some to be the most promiscuous feeder among the deer tribe, consuming all the grasses and most of the weeds within its reach, the leaves and twigs of all the deciduous trees alike being enjoyed The handsome Roosevelt elk, which inhabit the spruce forests and dense coastal brush of northern California, feed extensively upon sword fern (*Polystichum*), deer fern, bilberry, huckleberry, salal (*Gaultheria shallon*), salmonberry, wild lilac, willow, and various grasses [120] In times of deep snow elk often gather the twigs and leaflets of evergreens and to some extent the tree mosses and lichens [121]

The summer food of the white-tailed deer, in the northeastern forest, includes wild raspberry and blackberry, sarsaparilla, algae, pond lilies, deer grass, witch hobble moose wood, bracken, poplar, chokecherry, hard and soft maple, elderberry, nettle, beech, birch, and laurel [122] To these may be added a host of succulent aquatic plants and many flowering plants During the fall, deer feed extensively upon acorns and beechnuts and even after snow covers the ground the deer follow the beech ridges, pawing up the snow beneath the trees to uncover the nutritious beechnuts During this season, the chief food consists of browse, the deer feeding on practically every woody plant, although spruce appears to be largely ignored, at least in the western Adirondacks of New York Red maple, yellow birch, mountain holly, and witch hobble have special appeal for deer, and wild raisin, chokeberry, honeysuckle, and blueberry are eagerly eaten [123] Northern white cedar is a choice food wherever it occurs in the range of the white tailed deer Even though our dainty white-tails

are chiefly vegetarian, they occasionally develop unusual tastes Deer about a Maine camp developed a liking for trout and ate a number of these fish [124]

The mule deer (*Odocoileus hemonius*) is said to browse relatively more than it grazes, although at certain seasons fresh green grass forms a large share of its food The deer tend toward repeated but light utilization, taking a nip here and there as they pass by food plants In summer they feed extensively upon yard grass, meadow fesque, Spanish clover, western chokecherry, California black oak, Kentucky bluegrass, curly dock, and many others In the fall some of the principal foods are weeds, deer brush, goldenrod, tumble weed, sagewort, mugwort, and milkweed Milkweed is rarely touched during the summer, but after the hard frosts have killed the stalks the dry leaves are especially sought for and eagerly devoured [125] Mule deer are fond of acorns, discarding the shell and chewing the meat into a fine pulp

The black tailed deer feed extensively upon canyon oak and grasses during the spring and summer months and are attracted to the California lilac (*Ceanothus thyrsiflorus*) and buck-brush (*C auneatus*), which have been observed to be important foods [126] Its food probably does not differ materially from that of the mule deer

The moose (*Alces*) is primarily a browser, but it does not disdain grasses, weeds, and sedges Most of its food is secured from shrubs or low growing trees, although the great bulls and cows may straddle trees several inches through the trunk or push the trunk down with their huge muzzles The leaves, and to a lesser extent the twigs, of poplar, birch, hazel, dog wood, alder, mountain ash, pin cherry, hard maple, bush honeysuckle, sedge, asters, pondweeds, and mushrooms are eaten by the moose of Isle Royale in Lake Superior [127] In the winter these animals fed extensively upon balsam, white cedar, and, to a lesser extent, white pine and white spruce Where abundant food is available, the moose eat the tender terminal twigs of many hardwoods and with the approach of

spring consume great quantities of bark The writer has watched bull moose feeding during the summer months in northern Maine At this season they are attracted to the lakes and wade far out from shore, tearing up water lilies and other juicy aquatics At times the animals may be completely submerged as they root about on the muddy bottom for these prized foods

The woodland caribou (*Rangifer caribou*) have feeding habits not unlike the moose during the summer, resorting to lily pads and their roots and all manner of herbaceous plants During winter they dig through the snow with their broad hoofs uncovering various ground mosses and lichens, chief among which are *Cladonia*, *Cornicularia*, *Cetraria*, and *Bryopogon* In the event of deep snows, when digging for their food becomes quite impossible, the caribou browse on tree-growing mosses such as the common *Usnea* [128] Murie has given a good account of the food habits of the barren ground caribou (*R arcticus*) as observed by him in the Alaska Yukon country [129] He stresses the importance of lichens and grasses as a year round food of the caribou During the winter these big deer feed extensively upon crowberry (*Empetrum*), true mosses grasses and bearberry During spring and early summer willow and birch are extensively browsed Mushrooms are eagerly consumed during mid-summer

Reindeer were seen to eat their shed antlers, and Murie believes this curious habit may be shared to some extent by the caribou They also smell out and eat the stored caches of mice Mice and fish have served as food for caribou in times of stress [130]

Antilocapridae (Pronghorns) According to Caton[131] prong horn antelopes are strictly herbaceous feeders, avoiding arboreous food if left to their own choice During the winter Bailey[132] states, they pick the tips and buds from a great variety of bushes and plants that come above the surface of the snow but they also seek the warmer slopes and sheltered spots where dry grass may be obtained In spite of its uniqueness

there are yet many gaps in our knowledge of this peculiar indigenous beast, not the least of which is a thorough knowledge of its dietary predilections

Bovidae (Bison, Bighorn Sheep, Mountain Goat, etc) The American bison is essentially a grazing mammal, its principal food consisting of various short fine grasses, such as the buffalo grass (*Buchloe dactyloides*) The great herds of the past favored grama, buffalo, beard, bunch, and bluestem grasses Occasionally if they were hard put they ate sagebrush and other weeds [133]

Grasses, mosses, lichens, and willow browse constitute the mainstay of the musk ox (*Ovibos*) In the range of the musk ox snow covers the ground during the greater part of the year, and it then employs the hoofs, horns, and nose to break through the snow in order to reach the hidden saxifrage and mountain avens [134] Most arctic explorers state that lichens do not form a substantial portion of the musk ox fare, but grasses and flowering plants play an important role in their lives

The bighorn (*Ovis canadensis*) dwells in the mountainous sections of our Western states It is a fastidious feeder, eating nothing but the sweetest and most delicate of hillside or mountain grasses and flowers [135] Vernon Bailey, who has studied these big sheep in many parts of Western America states that they rarely feed upon grass, seeming to prefer the leaves, twigs, and fruit of a variety of plants The ripe fruit of cactus, including its chewed up pulp, were found in the stomach of a large Texas ram, but not a trace of grass was observed [136]

The mountain goat (*Oreamnos*) dwells in the rugged fastness of the northern Rocky Mountains and the coast ranges In this inhospitable climate the goats browse and find sufficient sustenance in the arctic alpine flora The food of goats in the Mount Rainier National Park was ascertained to be huckleberry, mountain bramble twinflower, Oregon grape, bunchberry, evergreen violet, pipsissewa, and rattlesnake

plaintain.[137] During the winter the goats remain at high altitudes, for here the snow is swept from the dwarf plant growth and food is always available. This is true in the Rocky Mountains, especially in Glacier Park,[138] but on Mount Rainier the rocks above timber line are frequently bathed in clouds and storms, the resultant glare ice making it impossible for the goats to secure sufficient food. They must then move into the valleys.

XENARTHRA (Armadillos, Sloths, Anteaters)

The American edentates are all primitive beasts, most of whom have a specialized diet. The teeth may be absent or reduced to simple molars, which are deficient in enamel and lack roots. They are thus restricted in what they may eat.

Dasypodidae (Armadillos). The peculiar nine-banded armadillo (*Dasypus*) is a resident of Texas and New Mexico, being abundant as its range extends into Mexico. Stomachs from Texas animals contained large quantities of earthworms, many kinds of beetles and their larvae, cockroaches, spiders, millipedes, centipedes, grasshoppers, large numbers of cutworms, ants, and traces of crawfish.[139] The armadillo has been accused of destroying the eggs of quail and wild turkey, but to the writer's knowledge there is no conclusive evidence on this score.

Anteaters. As their name implies, the tropical anteaters feed principally on ants. A Panama specimen (*Tamandua*) had at least a pound of ants in its stomach.[140] Most of these ants were in a larval condition, but some were winged.

William Beebe has made many tests with plants of various families and has found no food acceptable to the three-toed sloth (*Bradypus*) except cecropia or pump-wood (*Cecropia palmata*) and wild plum (*Spondias lutea*). The latter is refused by some individuals, and when the two are offered the plum is never touched. The leaves only of the plum are eaten, but of the cecropia the leaves, leaf buds, terminal shoots, petioles and main stem itself, where it is still green, are devoured with

relish[141] It is thus extremely difficult to keep them in captivity in Northern zoological parks, but the two toed sloth (*Choloepus*) feeds readily on fruit and vegetables when captive and possibly has a less restricted diet in the wild

SIRENIA (Manatees Dugongs etc)

Trichechidae (Manatees) The Florida manatee is strictly aquatic, spending its life in the deep quiet tropical rivers and lagoons, usually above the level of tidewater, although it occasionally makes its home in the brackish water or the protected bays about the coast The weak molar teeth permit it to feed only on the aquatic plants which its environment supports Manatee grass and water grasses supply all its alimental needs When feeding, the manatee is said to fan the strands of grass and seaweed into its mouth by means of the copious bristles which surround the mouth[142]

CETACEA (Whales Porpoises Dolphins)

So far as we know, whales feed entirely upon animal life The two great groups, whalebone whales (*Mysticeti*) and toothed whales (*Odontoceti*), have widely different food habits

Whalebone whales are equipped with a grid of brushy plates (Fig 30), which strain out the water and retain the minute life upon which these creatures feed The clumsy right whales skim the sea surface, passing through schools of small crustacea, which are retained by the baleen plates through which the water filters The great swift finner whales have short coarse plates and descend with great speed on the schools of small herring, sardines, and the inch long crustacea which swarm in the seas at certain seasons Their huge mouths are capable of retaining several barrels full, the powerful tongue squeezing out the water through the natural filter formed by their short whalebone (Fig 50)

The appetites of these oceanic leviathans are in keeping with their size The stomach of a humpback whale contained

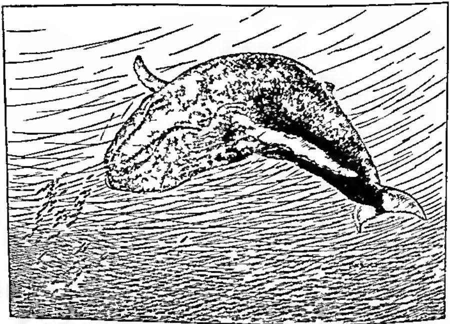


FIG 50 —All whalebone whales do not subsist on plankton The great humpback whale (*Megaptera nodosa*) consumes quantities of small fish Many barrels of herrings have been removed from the stomach of a single individual As a consequence of their piscivorous diet these great whales have coarse short baleen plates

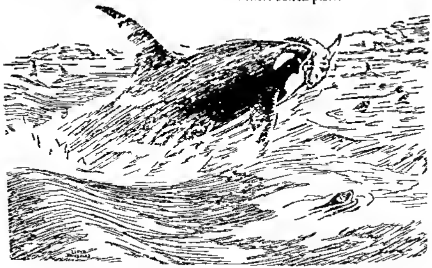


FIG 51 —The killer whale (*Orca*) is a fierce predator of the northern seas These swift cetaceans haunt the coast and bays attacking whales smaller dolphins and fish The stomach of one killer whale contained 24 seals

from 1,500 to 2,000 pounds of sardines and a miscellaneous assortment of other small fish and crustacea.

The toothed whales include the sperm whales, porpoises and dolphins and, as their name implies, are equipped with strong conical teeth. The huge sperm whale, reaching a length of 75 feet, feeds on fish, cuttlefish, and occasionally seals. The chief food of the sperm whale appears to be cuttlefish including giant octopuses which may measure 30 feet in length. To secure these squids, the whales may descend to depths of a thousand feet or more, where the squids are seized in the formidably armed and cavernous mouth of the cachalot. The great heads of these whales are often covered with marks of the suckers of the giant squid, tangible evidence of titanic struggles in the ocean depths.

The dolphins and porpoises feed on mackerel, herring, menhaden, and other gregarious fish. The white whale is said to feed on bottom fish, such as flounders and halibut, and is known to take cod, haddock, salmon, squids, and prawn.

The killer whales (*Orca*) are savage destructive cetaceans, known the world over for their predatory habits. Although they seldom attain a length exceeding 20 feet, they frequently assault huge whales, tearing at the lips and tongue. They feed on the giant tunny, kill the white whale, and occasionally drive schools of the huge blackfish on shore. Killer whales terrorize the seal rookeries, taking a fearful toll of the adults and pups alike (Fig. 51). The stomach of one killer whale contained 24 seals. Another had eaten 13 porpoises and 14 seals, yet was only 16 feet long.[113]

9) Wight, H M , 1928 *Jour Mammalogy*, 9 24
10) Moore, A W , 1933 *Jour Mammalogy*, 14 39
11) Hamilton, W J , Jr , 1931 *Jour Mammalogy*, 12 348
12) Brooks, Fred, 1908 *W Va Exp Sta Bull* 113 121
13) Hisaw, *op cit* , p 18
14) Svihla, Arthur, 1934 *Murrelet*, May
15) Shull, A Franklin, 1907 *Amer Naturalist*, 41 496–501
16) Merriam, C. Hart, 1884 "The Mammals of the Adirondack Region," New York, p 174
17) Svihla, *op cit*
18) Pittman, H H , 1924 *Jour Mammalogy*, 5 231–232.
19) Hatt, Robert T , 1923 *Jour Mammalogy*, 4 261–262.
20) Sherman, H B , 1935 *Jour Mammalogy*, 16 234
21) Nelson, E. W , 1926 *U S Dept Agr Bull* 1395 8–9
22) Campbell, Charles A R , 1925 "Bats, Mosquitoes and Dollars" Boston
23) Chapman, Frank M., 1933 "Autobiography of a Bird Lover," New York, p 133
24) Goodwin, George G , 1928 *Jour Mammalogy*, 9 104–113
25) Burt, William H , 1932 *Jour Mammalogy*, 13 365
26) Dunn, Lawrence H , 1933 *Jour Mammalogy*, 14 188–199
27) Green, E. E., 1911 *Spolia Zeylanica*, 7 216
28) Dunn, Lawrence H., 1932 *Jour Prev Med* , 6(3)
29) Bailey, Vernon, 1923 *Jour Mammalogy*, 4 53–54
30) Bailey, Vernon, 1931 *N Amer Fauna*, 53 354
31) Grinnell, Joseph, and Tracy I Storer, 1924 "Animal Life in the Yosemite," Berkeley, p 81
32) Goldman, E. A , 1920 *Smithsonian Misc Coll* 69 154
33) Nelson, E. W , 1918 *Nat Geog Mag* , 484
34) Abbott, C. G , 1884 "A Naturalist's Rambles about Home," New York, p 31
35) Criddle, Stuart, 1926 *Jour Mammalogy*, 7 199
36) Osgood, F L., 1936 *Jour Mammalogy*, 17 64
37) Leopold, Aldo, 1937 *Jour Mammalogy*, 18 99
38) Dearborn, Ned, 1932 *Univ Michigan, School For and Cons Bull* 1 31
39) Hamilton, W J , Jr , 1936 *Jour Mammalogy*, 17 169
40) Svihla, Arthur, and Ruth D Svihla, 1931 *Murrelet*, January
41) Seton, Ernest Thompson, 1929 "Lives of Game Animals," New York, 2(2) 434
42) Grinnell, and Storer, *op cit* , p 83
43) Hamilton, 1936 *op cit* , pp 240–246
44) Dearborn, *op cit* , pp 39–41
45) Bailey, Vernon, 1905 *N Amer Fauna*, 25 222.
46) Dixon, Joseph, 1925 *Jour Mammalogy*, 6 42–43
47) Dearborn, *op cit* , p 42.
48) Errington, Paul L., 1936 *Jour Mammalogy*, 18 213–216
49) Bailey, 1905 *op cit* , p. 184
50) Bailey, Vernon, 1936 *N Amer Fauna*, 55 305
51) Barabash Nikiforov, I., 1935 *Jour Mammalogy*, 16 258–259
52) Williams, Cecil S , 1938 *Jour Mammalogy*, 19 105–107

53) Hamilton, W J, Jr, 1935 *Jour Mammalogy*, 16 16–21
54) Dearborn, *op cit*, p 25
55) Nelson, E W, 1933 *Jour Mammalogy*, 14 40–43
56) Grinnell, Joseph, Joseph Dixon, and Jean Linsdale, 1937 Fur bearing Mammals of California," Berkeley, pp 447–449
57) Bailey, Vernon, 1928 "Animal Life of Carlsbad Cavern, Springfield Ill, p 95
58) Bailey, 1931 *op cit*, p 300
59) Grinnell, Dixon, and Linsdale, *op cit*, p 416
60) Seton, *op cit*, 1(2) 438–443
61) Seton, *op cit*, pp 376–378
62) Dixon, *op cit*, p 39
63) Sperry, Charles C, 1934 *Jour Mammalogy*, 15 286–290
64) Keller, L. Floyd, 1935 *Jour Mammalogy*, 16 232
65) Goldman, E A, 1930 *Jour Mammalogy*, 11 328
66) Bailey, 1905 *op cit*, p 177
67) Dearborn, *op cit*, p 29
68) Hamilton, W J, Jr, and Russell P Hunter, 1939 *Jour Wildlife Manag*, 3 99–103
69) Dickey, Donald, 1920 *Calif Fish and Game*, January, p 37
70) Taylor, Walter P, and William T Shaw, 1927 Mammals and Birds of Mt Rainer National Park, " Washington, p 57
71) Dyche, L L, 1902 *Trans Kansas Acad Sci*, 18 179–182
72) Merriam, C Hart, 1901 *Science*, 13(333) 777–779
73) Schultz, Leonard P, and A Morris Rafn, 1936 *Jour Mammalogy*, 17 13–15
74) Huey, Laurence M, 1930 *Jour Mammalogy*, 11 229–231
75) Scheffer, Theo H, and Charles C Sperry, 1931 *Jour Mammalogy*, 12 214–226
76) Griffin, Donald, 1936 *Jour Mammalogy*, 17 65–66
77) Dall, William H, 1902 *Rept of Smithsonian Inst for 1901*, p 683
78) Sutton, George Miksch, and William J Hamilton, Jr, 1932 *Mem Carnegie Mus*, 12(2) 51
79) Allen, Joel A, 1880 Monograph of North American Pinnipeds, Washington

94) Scheffer, Theo., 1938 *U S Dept Agr Bull* 1091 39
95) Vorhies, Charles T and Walter P Taylor, 1933 *Univ Ariz Agr Exp Sta Tech Bull* 49 471–583
96) Bailey, Vernon, and Charles C. Sperry, 1929 *U S Dept Agr Tech Bull* 145 10–19
97) English, Pennover F., 1923 *Jour Mammalogy*, 4 4–5
98) Howell, A Brazier, 1926 "Anatomy of the Wood Rat," Baltimore, p 10
99) Taylor, Walter P., 1915 *Proc Calif Acad Sci*, 4th series, 5 142
100) Rhoads, Samuel, 1903 "The Mammals of Pennsylvania and New Jersey," privately published, p 93
101) Bailey, Vernon, 1926 *N Amer Fauna*, 49 97
102) Quick, Edgar R., and A M Butler, 1885 *Amer Naturalist*, 19 113–118
103) Hamilton, W J, Jr., 1938 *Jour Mammalogy*, 19 166
104) Enders, Robert K., 1932 *Ohio Jour Sci*, 32 21–30
105) Svihla, Arthur, and Ruth D Svihla, 1931 *Jour Mammalogy*, 12 17
106) Grinnell, Dixon, and Linsdale, *op cit*, p 747
107) Evermann, Barton Warren, and Howard Walton Clark, 1920 "Lake Maxinkuc

134) Greeley, Adolphus W , 1886 **Three Years of Arctic** Service London, 1 104–105
135) Seton *op cit* , 3(2) 541
136) Bailey, 1905 *op cit* , pp 74–75
137) Taylor, Shaw, *op cit* , p 125
138) Bailey, Vernon, 1918 Wild Animals of Glacier National Park Washington p 30
139) Bailey, 1931 *op cit* , p 9
140) Goldman, *op cit* , 69(5) 63
141) Beebe, William, 1926 *Zoologica* 7(1) 37
142) Stone, Witmer, and William Everett Cram 1910 American Animals, Garden City, N Y , p 27
143) Rhoads, *op cit* , p 23

CHAPTER VI

STORAGE

At the approach of the rigotous Northern winter, those mammals which ate ahle to do so migrate to warmer climes Thus the red bat flies several hundred miles south of its summer range, to hang in a quiescent state during the chill days of winter Fur seals leave the arctic seas to feed and fatten in the suhtropical waters of the California coast. Many whales, too, seek a mote hospitable climate to heat theit young Elk and perhaps others of the deer tribe move into the valleys, where food is more easily procured. Many todents and a few of the flesh eaters retire to a warm nest in their suhterranean burrows or pass a prolonged lethargic petiod in a fallen tree Colonial bats repair to the even tempetature of extensive caves, where a constant temperature, usually from 45 to 55°F , prevails throughout the year. The cool temperatures result in a lowered metabolism, so that the bat needs little or no food

Those mammals which cannot flee the hostile periods of ice and snow or pass the winter in the profound comatose sleep of hibernation must have some ready supply of food with which to sustain life The hair seals find an abundance of fish, deer and rabbits secure browse; the meadow mouse still finds a wealth of green shoots and bark, while the flesh eaters, for the most part, subsist on meat. But what of the beaver, locked in by ice, or the tree squirtels, whose food is

often covered for weeks at a time by a deep mantle of snow? These, and many others which insist on an active winter existence, must lay aside large food stores, so that they will not suffer need in times of food scarcity

Cheek Pouches For the many small mammals which must provide storehouses of seeds for winter use, some means of transporting these foods must be available, for it is patent that the mouth cavity is not appropriate for this function Accordingly, the little pocket mice (*Perognathus*), kangaroo rats, and pocket gophers are all equipped with capacious external, fur lined cheek pockets (Fig 52) During the busy harvest season, these cheek pouches are crammed with food, which is thus transported to the underground storerooms The cheek pouches are filled simultaneously with rapid movements of the fore paws It has been stated by some that these cheek pouches, at least in the pocket gopher, are used to remove dirt from the tunnel Scheffer,[1] who has made a lifelong study of the gopher, insists that these cheek pockets are a structural adaptation for transporting food supplies only and that pocket gophers do not carry out in these pockets the earth excavated in burrowing Chipmunks and deer mice have well-developed internal cheek pouches When these are well filled with nuts, seeds, or berries, the animal has a ludicrous appearance, as though it were suffering from a severe case of mumps

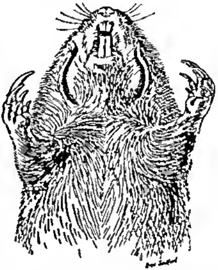


Fig 52—The pocket gopher is well adapted for a subterranean existence The lips meet behind the prominent incisors thus preventing entrance of dirt into the mouth when the animal uses these strong teeth for tearing roots The prominent external cheek pouches are used for storing food and the long claws of the fore limbs are a great asset to this digging rodent

Storage by Moles and Shrews Moles feed largely upon worms, insects, and, to a lesser extent vegetation In the northern part of their range frost penetrates the ground to some depth, necessitating deep tunnels or some provision for a well stocked larder While there is no positive evidence that American moles store food, Degerbøl[2] believes that the European species (*Talpa*) paralyzes earthworms, either by biting them in the head or by decapitating them The worms are then stored in chambers for future use

Shrews are gleaners, feeding on insects and other small animal life or eating a limited amount of mast and plant life Active throughout the year, it seems strange that they would be compelled to hoard food for the leaf mold and dense grassy fields which they occupy have a wealth of small life even when the ground is frozen Nevertheless, Shull[3] has made some pertinent observations which indicate that the short tailed shrew (*Blarina*) does lay aside stores His conclusions are that snails (*Polygyra*) are hoarded and in general are moved to the surface of the ground as the temperature falls below freezing and into the burrows as the temperature rises In the sides of one of the galleries of this shrew a small cavity was found by Bachman[4] and contained a horde of coleopterous insects principally large beetles (*Scarabeus tityus*) fully the size of the animal itself some of them were nearly consumed and the rest mutilated although some were still living The half-eaten remains of field mice have been found packed in the dirt about the tunnel of *Blarina* The habits of captive shrews certainly indicate a propensity for food storage The hoarding instinct in a captive nursing shrew was particularly pronounced

Storage by Flesh Eaters Many carnivores, owing to their dependence on flesh, must range widely during the winter months Food may be scarce and some species must provide for periods when prey cannot be secured Such provisions may be slightly covered with dirt or available trash or buried in a shallow snow grave to be consumed within a few days

Foxes, wolves, some weasels, cats, bears, and a few others store a surplus of food temporarily and may even stand guard over it or remain in the immediate vicinity to drive off lesser creatures which might be attracted to a free feast Murie[5] has noted that the red fox, when it captures more food than can be eaten, caches the surplus In winter, the caches contain rabbits, various mice, muskrats, and other small animals The writer has found pheasants buried beneath 6 inches of snow in New York, the work of a red fox Mountain lions are known to cache deer, returning to their larder until the supply is consumed The lion may remain in the vicinity of the kill, guarding its store for its own consumption against any possible carrion feeder When a mountain lion makes a kill, it frequently drags the carcass to a new spot, usually downhill At the completion of a meal the carcass is carefully covered with leaves, sticks, and pine needles which may be scraped over it An effort is made to cover the kill completely, for this will both hide and, in a measure, preserve it It is said that a kill may be buried, eaten upon, and reburied as many as ten times, although the carcass, once buried, may never be revisited [6] Grizzly bears often bury or otherwise hide the remains of moose, wild sheep, or other animals they have killed, feeding on them at intervals and remaining near alertly and guarding them fiercely Olson believes that timber wolves habitually store any excess food and under primitive conditions will return to these caches when hungry The fact that wolves are often trapped or poisoned at an old kill suggests that slaying of a number of deer at one time is not sheer wantonness, but rather an inherent act of storage, even though the prey be left as it fell Weasels often store quantities of mice and other small game, apparently returning to the caches when hunting proves fruitless The writer has come upon these stores on several occasions

Storage by Rodents Of all our American mammals which store food none are better known than the tree squirrels Both red and gray squirrels are provident creatures laying by

sizable caches for winter use. Nuts are the chief item, among which acorns, beechnuts, and hickories are most important. If the buried acorns should start to germinate in the spring the squirrels may dig them up, clip off their sprouts and rebury them.[8]

In the North, the red and pine squirrels are, to a large extent, dependent on the seeds of various conifers (Fig. 48). The cones are stored in the damp earth until such time as they are needed. Often these food stores are removed to a favorite feeding site, and the refuse or waste resulting from such feasts may form sizable midden heaps. A kitchen midden in a dense spruce thicket measured more than 9 feet in height and 12 feet in diameter. An elaborate food cache of an Alaskan red squirrel contained about 2 bushels of high bush cranberries, 2 bushels of alder cones and nearly a bushel of cow parsnip seeds.[9] The red squirrel is partial to mushrooms and stores great numbers of these during the summer. Fungi are hung in a crotch of a branch, there to dry and cure. Later they are stored in a stump or in the ground, but may remain in the branches until eaten. The red squirrel seems immune to the toxic qualities of the poisonous amanitas, for these mushrooms are eaten in some quantity, as the writer has had opportunity to observe.

How do squirrels find these buried stores? Do they rely on memory, trust to smell, or happen on the covered treasures by chance? Anyone who has watched a squirrel running over the several inches of snow, sniff here and there, then abruptly come to a halt, dig unerringly through the white mantle, leaves, and dirt and recover a buried nut cannot doubt the marvelous delicacy of their smelling powers. Several naturalists have tested this sense of smell and conclude that this is the primary method of detecting the hidden stores.

In selecting nuts for storage, squirrels seem to sense which are wormy and quickly reject them. The little chickaree (*Sciurus douglasii*) has been observed to grasp hazel nuts with its fore paws, put its nose to them, apparently making con

tact for an instant, and then turn away. In no case was a nut gathered which had been so tested. When the husk was removed from the rejected ones, it was seen that in every case a wormhole was exposed; this led the observer to believe that there must be a recognizable odor to a wormy nut, perceptible to a squirrel within a very limited distance. The squirrel apparently smells the nut to confirm its suspicion.[10]

Chipmunks make caches at all seasons, but there are no busier rodents in the autumn woods than these. This light hibernator is up and about during the mild spells of winter, and it is probable that it utilizes its extensive stores throughout the colder months. More than a bushel of hazel nuts have been found in the chambers of one chipmunk. It never stores food which might spoil, although the pouches sometimes contain slugs, snails, and ripe berries.

The hibernating ground squirrels (*Citellus*) make provision for food scarcity by putting aside large quantities of seeds and nuts. Why they should be concerned with storage is something of a mystery, for the greater part of the winter is spent in a torpid condition, certainly in the northern part of their range. It may be these caches are chiefly used during the early spring, when hibernation is ended but food yet remains scarce, or the stores may provide their alimental needs during periods of inclement weather before and after the long winter sleep.

Deer mice (*Peromyscus*) harvest great quantities of nuts, seeds, and pits for winter use. Subzero temperatures do not keep these graceful little creatures at home, and the snow-covered ground is covered with their dainty tracks during the coldest periods of midwinter. Accordingly they must store suitable supplies for these rigorous periods. The writer has often happened on stores of food made by the deer mice. Once, when a large beech was being felled, the rotten crown of the tree broke open, spilling on the snow at least a peck of beechnuts, a good share of which had been husked. Two deer mice were found in a warm nest of the cavity, which was at least 40 feet high. The seeds of basswood, wild cherry,

shrubby dogwoods, and of many herbaceous plants are placed in these mouse granaries Several quarts of clean seed of red clover were found within a stump in a clover field in western New York, collected by a family of these mice [11] While collecting on Mount Katahdin in northern Maine a number of years ago, the writer trapped several of these mice in August, which even then were filling their cheek pouches with the tiny seeds of blueberry

The pocket gopher feeds on the fleshy roots and underground stems of various plants growing wild in its habitat The plant structures are sectioned into convenient length, usually an inch or so, stored in the cheek pouches and transferred to the underground chambers These are usually situated near the surface in chambers which are connected with the feeding runways This arrangement simplifies the transportation of supplies in the harvest season Scheffer[12] has given a good account of the storing habits of the pocket gopher He states that the animal follows instinct in storing, for when food supplies are abundant, it will cache them away without stint of labor, though much of the food may not be used and subsequently spoils In the Pacific Northwest, where the pocket gopher s harvest season may cover the entire year, the little animal appears to store as abundantly as it does in regions of severe winters, where the soil freezes to considerable depths

Field mice and their allies usually do not store great quantities of food for winter use, as roots, bark, and green sprouts are often available throughout the winter Couch[13] states that in western Washington there is an abundant supply of green succulent food available during the winter months, yet the large Townsend meadow mouse seems to prefer making stores and feeding from them to foraging for its nightly subsistence As much as 14 quarts or more of these roots were found in a single cache

The little bean mouse (*Microtus pennsylvanicus wahema*) differs from its near relatives in its choice of habitat, selecting

open, sparsely covered semi-arid regions. The lack of available food during the winter necessitates extensive storage of food, and the mice collect and store great quantities of the underground beans of *Falcata comosa*, the long tubers of wild artichoke (*Helianthus tuberosa*), and the little white tender roots of wild morning glory.[14] The mouse burrows enter the ground from several sides, and the cavity where the food is stored often holds a peck or more of beans and tubers. Bailey mentions the importance of these fresh vegetable stores to the meat diet of the hunting Indians, who dig them extensively during the late fall. In his survey of the Dakotas in 1855, Lieut. G. K. Warren[15] mentioned the usefulness of the ground nut (*Apios tuberosa*) to the Indians and how they collected the stores from the mice; he sometimes found several bushels of the tubers in a single lodge.

The writer has often found stores of cut stems, tender blanched shoots, and the fleshy rootstocks of the morning glory packed in the tunnels of pine mice (*Pitymys*). It does not seem probable that these are cached for winter use, as the mice are up and about throughout the year and food is usually abundant at all seasons.

The red-backed mouse (*Clethrionomys*) provides for winter by garnering great quantities of beechnuts and perhaps other nuts and seeds. The writer once saw one of these mice running busily over the leafy carpet of a Northern forest, searching for the fallen beechnuts. It placed a nut in each cheek, held one securely in its teeth, and carried these off to its subterranean chambers beneath an old stump. Repeated trips were made, until a sizable store had been collected. Inasmuch as this was observed in the late fall, it is probable the stores were made for the long winter season when food might prove difficult to find.

Curing of Food for Winter Use. Several species of mammals gather their harvest and dry it before it is stored in the winter chamber or cache. This is often quite necessary, for, although the food may be collected in the dry desert or warm rockslides

of exposed mountain slopes, it would quickly spoil were it to be taken into damp underground chambers or stacked in great piles while still having a high water content Some species have adopted ingenious methods for preventing such spoilage only a few instances of which may be detailed here

Kangaroo Rat In the dry plains of the West, the winter rains give promise of a fair vegetation Considerable green vegetation may be seen by late February, but as the rains cease the plants quickly flower, form seeds, and die In an area where there may be as little as 1 inch of rain a year and where there is seldom more than 4 or 5 inches, the annual vegetation seldom attains any size, and the pepper plants seed when but 1 inch tall By early summer the countryside is usually one of bareness Wind action and drought, together with overgrazing, render the territory destitute of vegetation Kangaroo rats, deer mice and other small mammals are present in such places often in some numbers One wonders how these little animals can survive under such inhospitable conditions

The studies of Dr W T Shaw[16] have shed new light on the habits of these desert rodents In the arid country about Fresno California Shaw found that the giant kangaroo rat (*Dipodomys ingens*) was unusually active in the late winter and early spring This activity was induced by the necessity for garnering a sizable store of seeds for the long drought period when little else is available

If these green gathered seed pods were collected and immediately carried to the depths of the den where at this season the soil is moist they would soon result in a total loss from molding Excavation of these burrows reveals no trace of fresh material However all about the den on rhe surface of the ground lirtle pits about 1 inch in diamerer and 1 inch deep, are made by the provident kangaroo rat and in rhese remporary storehouses are placed quantiries of seeds chief among which are pepper grass evening primrose and filaree Shaw suggests that this material might be left in this thor

oughly dry situation, even protected from light rains which might possibly occur, by the coveriog of dust Repeated days of warm to hot sun might do the curing At any rate, the stores are left io these little surface-of the ground caches for two mooths or looger, when, thoroughly cured and dry, they are removed to the undergrouod chambers of the kangaroo rat

In southeastern Arizona storage of food takes place during two seasons, in the spring, during April and May, and in the fall, from September to November, the latter heing the more important For the periods between, the animal must rely latgely on stored materials The kangaroo rat (*Dipodomys spectabilis*) of this region apparently stores the greeo seeds directly in the underground chambers During September, when a good ctop of gtass seed was ripeoing following the summer rains, a kangaroo rat uoder observation made repeated round trips to the harvest field of grass heads Each outward trip occupied 1 to 1½ minutes, while the unloading trip into the burrow took ooly 15 to 20 secoods[17]

Pika One of our most ioteresting Western mammals is the little chief hare or pika, a miniature rabbit-like creature of the Rockies Like its congeners, the true hares, this little beast remains active throughout the year, so that it must be of a provident nature to survive during the bleak severe winters Late in the summer the pika commences its haymaking, cutting various plants which grow near its home and spreading these out on rocks, stumps, or logs to dry (Fig 53) When this store is properly cured, which may take from a few days to a week or more, the pika transports it to some dry crevasse or shelter in the rock slide, to feed leisurely on these stores while winter storms rage above the protective blanket of snow A large haystack examined by Bailey[18] in New Mexico was placed in the shelter of an overhanging point of rock and was composed of a bushel of thoroughly dried, half-dried, and freshly cut plants, the last always on top Under most of these haystacks were found the remains of stacks of previous

years In this particular slide, the snow of the previous winter had not all disappeared by the middle of August, for the great drifts and avalanches must pile up many feet of depth during the winter The little animals are thus well protected in the roomy chambers among the huge boulders and broken rocks and have little to fear from the elements or predators

Mountain Beaver The little mountain beaver (*Aplodontia*) of the mountainous Pacific Coast states remains active all

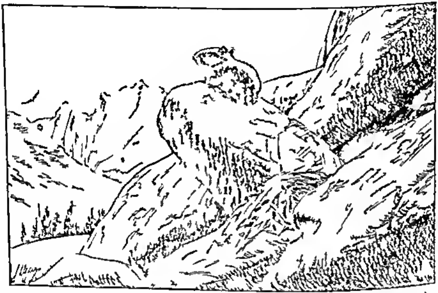


FIG 53 —The cony and its hay pile These little rabbit like animals live among the boulder-strewn slopes of western mountains They industriously gather grasses and herbaceous plants store them in piles until they are sufficiently cured then place these stores in suitable quarters until they are needed

winter In early August it commences harvesting operations cutting off numerous sprays and disposing them in neat piles to dry on rocks, logs, or stumps about the entrance of the burrows [19] After the plant material thus collected has dried it is removed into the burrow, either for winter food or for nest lining

Moisture and Its Relation to Cone Storing Most important among the food items of Western red squirrels are the seeds of various pine cones In the great forests of Western America the giant sequoia, Douglas fir, white fir, and many pines pro-

duce a tremendous crop of seed As the seeds ripen, the cones open to release these myriad winged seeds, and by late summer or early fall many have been scattered by the wind With this wind distribution accomplished, the squirrel's favorite food would be lost had it not anticipated this very act weeks earlier

The careful studies of Shaw[20] have shed light on the time of harvest by the pine squirrels and the reason for this Shaw observed that squirrels are busy cutting the green cones by early July, long before the time when they would normally ripen These cones are then stored along the margins of little spring runs, some being buried below the water but all placed in damp recesses or depressions, which are used year after year The cones are not covered, as this would prove disadvantageous at the time of retrieving them, when they are held down by frost and snow In order that the cones may remain closed and retain their seeds, it is necessary that they be moist If exposed to drying winds or the sun, the cones open and the seeds are expelled in a few days Hence the necessity of placing this important food where it will receive a constant supply of moisture

This interesting and natural response of cones to water, as Shaw explains, must be of great value to the pine squirrels in storing their harvest and, later, in enabling them to survive adverse conditions, such as years of cone-crop failure Such a method of cone storing in wet situations is generally adopted by the pine squirrels of Northwestern America That moisture is a most important factor in preserving the cones is quite evident, for it is necessary not only that the cones be tightened to preserve the seeds, but that they be kept so for a long period, often several years

Underwater Storage. The beaver stores quantities of sticks and even sizable trees, perhaps 5 inches or more in diameter After the tree is felled, the larger limbs are trimmed and dragged to some deep spot near the lodge or near the bank if the beaver is living in a tunnel Since only the bark is utilized, it requires much industry on the part of the colony to provide

sufficient stores to tide them over the long Northern winter As a consequence, storage activities commence in late summer and continue until winter sets in Stores of limbs often remain at the close of winter, indicating that beavers usually are provided with plenty As food is needed the beaver swims to its food pile, gnaws off a section of limb, and returns to the

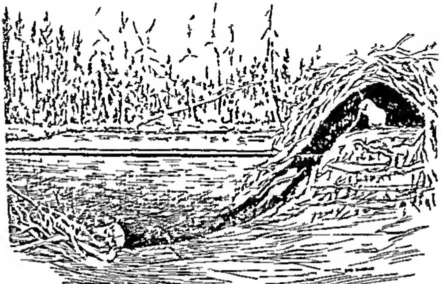


FIG 54—The beaver's lodge and food store Ice often makes a virtual prisoner of the beaver during the winter At this season it must rely on the store of large limbs and small trees laboriously gathered during the fall These are dragged to the deepest part of the pond and to these the beaver repairs when it is hungry A limb is transported to the lodge the bark eaten and the remains carried to the dam

lodge (Fig 54) After the bark is eaten, the peeled stick is cast out or used to repair or add to the dam or house

The heavier timbers which are to be used for food are carried to the bottom and partly buried in mud A little is sufficient to hold it down as the green stick is nearly as heavy as water It shortly becomes water-logged and remains sunk even though uncovered "[1] If the beaver lodge is situated in a current, a pile of brushwood, which is not utilized for food is moved to the bottom Among this are stored the smaller twigs "

BIBLIOGRAPHY

1) Scheffer, Theo H, 1931 *U S Dept Agr, Tech Bull* 224 16
2) Degerbøl, Magnus, 1927 *Vidensk Meddel Dansk Naturhist*, 84 195–202
3) Shull, A Franklin, 1907 *Amer Naturalist*, 41 495
4) Audubon, John James, and John Bachman, 1849 Quadrupeds of North America New York, 2 p 177
5) Murie, Adolph, 1936 *Univ Mich, Mus Zool, Publ* 32 25
6) Hibben, Frank C, 1937 *Univ New Mexico Bull Biol Ser* 5(3) 36
7) Olson, Sigurd, 1938 *Scient Monthly*, Apr p 333
8) Walton, M A, 1903 A Hermit s Wild Friends, New York, pp 87–88
9) Murie, Olaus J, 1937 *Jour Mammalogy*, 8(1) 37–40
10) Mailliard, Joseph, 1931 *Jour Mammalogy*, 12(1) 68–70
11) Kennicott, Robert, 1857 *U S Patent Off Rep Agric* 91
12) Scheffer, *op cit*, p 16
13) Couch, Leo K, 1925 *Jour Mammalogy*, 6(3) 200–201
14) Bailey, Vernon, 1916 *N Amer Fauna* 49 96
15) Warren G K, 1856 *U S Congress 34th Senate Doc* 76 78
16) Shaw, William T, 1934 *Jour Mammalogy*, 15(4) 275–286
17) Vorhies, Charles T, and Walter P Taylor, 1922 *U S Dept Agr Prof Paper Bull* 1091 1–40
18) Bailey, Vernon, 1931 *N Amer Fauna* 58 66–67
19) Taylor, Walter P, and William T Shaw, 1927 *U S Dept Interior, Nat Park Service*, p 86
20) Shaw, William T, 1936 *Jour Mammalogy*, 17(4), 337 349
21) Seton, Ernest Thompson, 1929 Lives of Game Animals New York, 4(2) p 485
21) Morgan, L H 1868 The American Beaver and His Works New York p 188

CHAPTER VII

REPRODUCTION AND EARLY LIFE

THE breeding behavior and early life of mammals are among the most fascinating of all subjects with which we have to deal. The selection of mates, the aggressive battles between males for a harem, the abortive or advanced condition of various species at birth, and the remarkable infancy of many others, have all excited wonder among those who have been fortunate enough to study these matters. In the account which follows, little attention will be directed to the prenatal life of American mammals. Many justly famous reports have been prepared on the embryology of mammals, the information about some being so meager that little is truly known of the post natal existence of the animals. A study of the breeding behavior of an animal may give us much insight into its other habits and a careful review of its early life cannot fail to provide us with clues to its later life, or the mode by which it has progressed the evolutionary ladder to its present state.

The Sexual Cycle. The sex organs of mammals are too well known to call for extended discussion. Figure 55 illustrates the salient parts of the male and female reproductive system. The naturalist should become familiar with these, for a proper understanding of the structures is of utmost importance to those who contemplate a study of the breeding behavior of a species.

The paired testes and their associated structures are the reproductive organs of the male. In most rodents, bats, and

insectivores they usually lie within the body except during the breeding season, when they descend In the marine animals, anteaters, and a few others they retain the primitive internal position at all times Among ungulates, the testes lie within an integumentary sac, the *scrotum*, at all seasons The scrotum customarily lies in front of the penis in the marsupials Prominent convoluted tubes, the *epididymes*, store spermatozoa, which are released by the testes when mature These tubes in turn give up the sperm to the *vasa deferentia* These eventually lead to the *urethra*, which is housed within

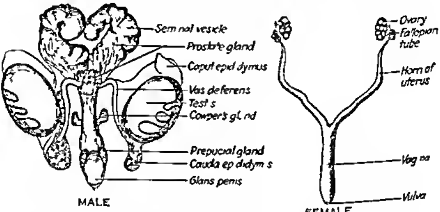


Fig 55 —The reproductive organs of the field mouse (*Microtus pennsylvanicus*)

the penis This latter structure acts as an intromittent organ during copulation Associated with the vasa deferentia are other accessory organs, a *prostate gland* and a pair of *bulbo-urethral glands* or Cowper s glands which open into the urethra Their secretions make the seminal mass more fluid An *os penis* is present in most primates, carnivores, rodents, and a few insectivores and bats The bone appears to be of some systematic value

In the female the paired ovaries are small flattened oval bodies often scarred or exhibiting rounded projections on the surface clearly marking the *Graafian follicles*, which house the egg The human ovum is so tiny that 1,800 ova, placed end to end, would scarcely stretch an inch, nor are those of a 90-foot

whale any larger or those of a mouse appreciably smaller The *oviducts* transport the liberated egg, through their aoterior *Fallopian tube*, to the middle uterus, where the developing egg becomes implanted in the wall by the *placenta* The uteri unite posteriorly to form a *vagina* At the veotral lip of the urioo genital canal occurs a structure known as the *clitoris*, which corresponds to the peois of the male This structure is often times very promioent (in some monkeys it may actually ex ceed the peois in size), and maoy collectors have been misled by its promioence into believing they were handling a male

Great changes occur in both male aod female reproductive organs from the non hreediog to the breeding season More over, structures common to one species may be quite lacking in another or so radically different in appeatance that their true identity may scarcely be recogoized

The males of many species of mammals have a definite season during which they may breed, although it frequently happens that they are capable of fertile copulation at any season This function is restricted in the female to definite periods occurring at varying iotervals from a few days to a year or more The time at which fruitful mating may occur io the female is known as the oestrus

Several prooounced stages in the oestrous cycle have been outlined by Heape [1] The first of these, the *anoestrous* period, is characterized by a period of rest io the reproductive organs of the female, coincident with the non hreeding seasoo The uterus is oormal and somewhat anemic, aod the female shows no dispositioo to mate In many mammals this period may be prolonged, occupying the greater part of the year With the approach of the hreediog seasoo, a marked change occurs in the generative organs The uterus becomes swollen the vagina enlarged and turgid, and the animal comes in heat This period is known as the *pro-oestrum* and is often accom panied at its close by a flow of blood from the vagina

The prooestrum is followed by the *oestrum* which marks the period when the female is receptive to the male and fruitful

coition made possible If conception takes place at this time, pregnancy normally occurs Lactation follows gestation, to be succeeded by another quiescent period of anoestrum at the end of the breeding season It has been stated that lactation is an insurance against the immediate resumption of the oestrous cycle [2] Nevertheless, parturition in some mammals, notably members of the Muridae, is followed immediately by another oestrous cycle Field mice may have fruitful coition within an hour following parturition, while other voles and the deer mice frequently mate immediately after the birth of their young

If fruitful mating does not occur during oestrus, the period is followed by a short *metoestrum*, during which the female genitals resume their normal condition In some polyoestrous animals (*Peromyscus*, *Rattus*) the metoestrum is followed by a rather short period of quiescence before the return of the succeeding oestrous cycle This period is known as the *dioestrum* Thus this dioestrous cycle, as it is called, is repeated until the close of the breeding season The duration of the dioestrous cycle in the Norway rat is said to occupy 4 days, in the house mouse 4 to 6 days, in the deer mouse (*Peromyscus*) nearly 5 days, and in the cotton rat (*Sigmodon*) from 5 to 9 days [3]

Some mammals have a single oestrous period during the breeding season These are known as *monoestrous* animals Even though an animal has only one annual sexual season, we cannot be certain that this consists of more than a single oestrous cycle Furthermore we cannot by analogy assume that wild animals, however closely related they may be to domesticated stock, react similarly The wild pig has a single annual sexual season, although we know the domestic sow to be *polyoestrous*, mating five weeks after partus Dogs, and probably foxes, bears, seals, and bats are all monoestrous

Those species in which there is a recurrence of the dioestrous cycle in the breeding season are said to be polyoestrous This condition is common to the smaller mammals notably the rodents Inasmuch as they are subject to consider

able predation, it is tantamount to survival that they breed frequently, and this polyoestrous condition provides more frequent opportunities for a successful mating The ubiquitous field mice and shrews, tree squirrels, and lagomorphs all experience a recurrence of the oestrous cycle during the prolonged breeding season

Even though a species has a single litter a year it may exhibit a polyoestrous condition The Columbian ground squirrel (*Citellus columbianus*) has recurrent periods of oestrus It not infrequently happens that the opportunities for breeding are lost Under such circumstances the squirrel returns to oestrus in about two weeks [4]

The domestic cat is polyoestrous and it is not improbable that its wild progenitors are also, for in a captive lioness oestrus has been known to recur at intervals of three weeks until the animal became pregnant while the period of oestrus itself may last a full week [5]

THE BREEDING SEASON

The season of reproduction is normally considered to be that period when adult animals are concerned with mating and the care of the young This season is often confined to a stated period in many species, while others breed irregularly at various times of the year American monkeys appear to have no breeding season, for all sizes of infants and juveniles may be seen at every season

The length of time during which he is preparing for, and capable of, inseminating the female determines the extent of the breeding season for the male This may be a matter of several weeks among the carnivores and deer, which are said to have a rutting season, it may last through half the year in wild mice, and monkeys are apparently capable of fruitful mating at any season Males of many domestic mammals (dog horse, and bull) seem always capable of inseminating the female Captivity often modifies the sexual season of males Wild elk have a limited season of reproduction in the fall but

some captive males are said to rut all the year round except during the season when the antlers are lost and are being renewed

The breeding season in the female includes the sexual (oestrous) and gestation periods jointly There may be but a single sexual and gestation period in the breeding season of some species, this being true of all monoestrous mammals, of which the fox will serve as an example, or it may include several sexual seasons and several gestation periods, such a condition being attained in many native mice and tree squirrels

Seals, ungulates, carnivores, bats, moles, and many other mammals have rather regular periods during which breeding occurs The time of fruitful mating may be limited to a few days, or the female may remain receptive at recurring intervals over several weeks

Climatic conditions often influence the season of reproduction, mammals in southern latitudes often having a longer breeding period than that of their northern kin That such a condition does not always prevail is shown by studies[6] which have demonstrated that field mice in the north of Great Britain have a much longer breeding period than their southern relatives

The breeding season may likewise be influenced by the abundance of the species When cyclic species (field mice and varying hares) are unusually numerous, the reproductive period is prolonged When the inevitable population decline occurs, there is evidence that not only is the season for reproduction curtailed, but the number of litters and their size are materially reduced[7]

Among those species which have a relatively slow development, birth normally occurs during the late winter or early spring In the North a reasonably long time is thus provided for the growth of the young prior to the onset of severe weather The ungulates, carnivores, and those rodents which produce but a single annual litter all produce young in the

spring Bats have but a single family each year, partus normally occurring in early summer, but the rapid development of the young is sufficient to prepare them for the winter

Gestation The period of gestation is roughly correlated with size, small mammals having a shorter period than large species Many mice and rats have an intra-uterine life of 3 weeks, ground squirrels have a 24 to 32 day period, rabbits and hares carry the foetus from 30 to 36 days, the smaller cats have a period of 51 days, and most of the dog tribe normally have a gestation period of at least 9 weeks The gestation of the great whales is not terminated until 20 months while the elephant has a prenatal life of 22 months

The length of gestation is likewise determined by the condition of the young at birth Those species in which the new born are relatively advanced have a lengthened gestation As a rule the duration of gestation is longer in those species which bear only one or two at birth than in those which produce litters

Marsupials have a very short gestation, the young are consequently born in a most undeveloped condition, 'living abortions,' as it were After an intra uterine stay of 12½ days, the tiny young opossum (Fig 56), so small that 18 may rest secure in a teaspoon, are born The studies of Hartman[8] have shed much light on the reproductive behavior of this unique American marsupial Actual observation of partus in the Virginia opossum indicates that the young are born into the world with sufficient neuromuscular coordination and sensory response to clamber from the vaginal orifice into the pouch The front legs and feet are highly developed and provided with sharp hooked claws, while the hind limbs are mere buds or pads At birth the young opossum climbs with a hand-over-hand movement like the strokes of a swimmer It moves about in this maze of hair until its muzzle touches the nipple It remains in the pouch for nearly two months

Most of our bats mate in the late summer or fall, but ovulation and fertilization do not occur until the following spring

The mass of spermatozoa is stored in the vagina or uterus and held immobile by a plug formed from the epithelial cells of the vaginal walls. It is assumed that in the spring, with the occurrence of ovulation, the follicular fluid and other secretions descend into the uterus, diluting the plug and releasing the sperms, which then ascend the tube and cause fertilization.

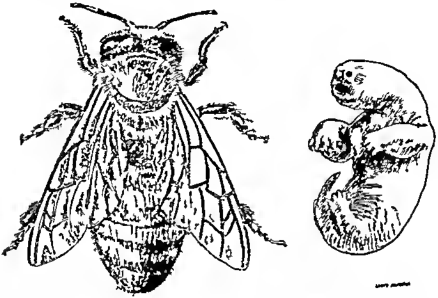


Fig. 56. A newborn opossum (*Didelphis virginiana*) and a honey bee. The diminutive size and undeveloped condition of marsupials at birth has long attracted the attention of scientists to this group. Note especially the strong fore limbs and prominent hooked claws of the hand, which are used to pull the youngster into the pouch at birth. The circular mouth grasps a teat and remains attached for weeks. The rest of the animal is embryo-like in appearance.

The variable temperature of the bat, notably its lowered temperature during the winter months, would favor the survival of the sperms, as would the inhibiting influence of the vaginal plug.

A study of the reproductive cycle in cave bats has convinced Guthrie[3] that copulation regularly occurs in the spring as the hats are aroused from hibernation. It was recognized that these cave bats mate in the fall, and Guthrie's studies show

that bat sperms do remain active for unusually long periods in the tract of the female, although the studies do not lend conclusive support to the hypothesis that the sperms of the autumnal insemination are responsible for the vernal activation

It has been noted that apparently the environment may cause a hibernating bat to ovulate If a bat is removed from its hibernating quarters after mid winter and placed in a warm room, ovulation occurs A group of brown bats (*Eptesicus*) captured by Gates[10] in May all gave birth to young within 48 hours of one another Such evidence is indicative of simul taneous ovulation on the part of all the females and tends to support the theory that spring copulation is not necessary, for it seems hardly possible that these bats would all have mated within such a short time Simultaneous parturition is therefore a result of favorable spring conditions resulting in ovulation, the sperms having been stored in the oviduct and uterus since the previous fall

Delayed Implantation The intra uterine development of some mammals undergoes an interruption not unlike that which we find among reptiles and birds, thus prolonging the gestation for lengthy periods

Usually fertilization takes place shortly after ovulation As the ovum passes into the uterus cleavage has occurred and the blastocysts then come in contact with the uterine walls and implantation occurs The cells not concerned with form ing the placenta go on to form the embryo, development thus proceeding continuously throughout intra uterine life This ceaseless process finally results in the formation of a fully developed embryo, when partus occurs In marked contrast to this is what is termed discontinuous development The preliminary stages are similar until the blastocyst stage is reached Abruptly development halts and may not be resumed for weeks or even months The purpose of this quiescent stage has not been satisfactorily explained We find this situation in a number of mammals, the gestation period being

some months longer than that in which embryonic development occurs The marten, fisher, badger, weasel, armadillo, and, possibly, black bear have this prolonged gestation The normal breeding season in the marten occupies the summer months, usually from the middle of July to late August Gestation may last from 8½ to 9 months, whereas its congener, the mink, breeds in late winter, the young usually being born 42 days after mating Hamlett[11] has described the complete reproductive cycle in the nine-banded armadillo, in which species he found the free vesicle to have a quiescent period of about 14 weeks

Lactation is an important factor in lengthening gestation King,[12] reporting upon the rat, observed that when a large number of young were suckled the length of gestation was always increased The duration of gestation was also increased when a very large number of embryos was carried The deer mouse (*Peromyscus*) has also been observed to have a lengthened gestation when nursing young [13]

THE YOUNG AND THEIR CARE

Development of Young at Birth We have seen that the length of gestation may determine the condition of the young at birth As almost everyone knows, newborn rats, after a uterine development of 3 weeks, are born in a blind, naked, and helpless condition, wholly dependent on the parent for a number of days The guinea pig, but slightly larger, has an intrauterine life twice that of the rat and as a consequence the young are born in an advanced condition, well furred and with eyes open, and are dependent on the parent for a rather short period This instance alone shows the impossibility of drawing a hard and fast line between pre- and postnatal characters

A newborn opossum (Fig 56) is not so large as a bee and must spend a long period in the sanctuary afforded by the maternal pouch The diminutive size and premature appearance of newborn bears are quite remarkable and have excited

much attention At birth the young are scarcely larger than red squirrels and weigh but 10 or 12 ounces Born as they are in mid winter, it is necessary for the mother to cover them nearly the whole time during the 2 months following their birth The eyes of young black bears do not open until they are 6 weeks old, and another month elapses before they leave

Fig 57—A new born porcupine (preserved) The young are very precocious and can eat leaves and tender shoots within a day or two of birth Contrast this with the diminutive young of the opossum (Fig 56)

the den of their own accord An adult porcupine weighing 12 pounds will bear a 1 pound baby which is actually larger than a newborn black bear But the young porcupine is born in an advanced condition, with well furred body, spines which soon stiffen, and a desire for solid food in a day or so (Fig 57)

The ungulates, living a nomadic life and beset by the larger carnivores, usually beget well-developed young We can observe this among our domestic stock the long limbed ac-

tive foal or the calf which rises on shaky legs to nurse a half hour after partus. The buffalo calf is able to follow its parent within a few hours after birth and well it must, for wolves and coyotes were ever ready to destroy the youngsters in the days when all were abundant. The forest loving deer is less nomadic than the bison of the plains and its young, while well developed at birth, is not so precocious as the buffalo calf. Young deer are hidden in a thicket for several days after birth, until their limbs become sufficiently strong to permit them to follow the doe.

The young of cetaceans, born as they are in the water, must pass a long intra uterine life and be well developed at birth. That this situation prevails is evident from their large size. The blackfish (*Globicephalus*) bears a single young which at birth is nearly half the length of its parent. Newborn porpoises are nearly half as long as their mother.

Within the same family we find diverse conditions among newborn young. The jack rabbits of our Western plains produce advanced young, well furred and with eyes open. Full term babies have been taken from jack rabbits and, after being freed from the foetal membranes, the young soon establish respiration and struggle to a sitting position. They exhibit a defense mechanism even at this early age, for, when touched on the nose one tiny jack rabbit reared on its hind legs and would strike or feint with its fore paws, assuming a very threatening attitude.[14] They may be born in a shallow shelter excavated in the ground, but some jacks and the varying hare provide no nest for the reception of the young, these being scattered about wherever cover is available. Contrast these precocious infants with the cottontails (*Sylvilagus*), of which the young are born in quite a helpless condition. Their eyes do not open until a week after birth and their bodies are clothed in a tomentose pelage for several days. They must have the shelter of a warm nest, which is lined with fur furnished from the mother's own body. The young do not leave the shelter of the nest for 10 or 12 days. The European

rabbit brings forth her young in a burrow, but our cottontails usually provide a shallow excavation closed by grasses and fur while the mother is absent from the nest

Fecundity The number of young produced in a season is dependent on many factors, but none are more directly responsible for the fecundity of any species than are its enemies and the environment it has selected in which to produce these young In general, it may be said that small mammals produce a greater number of young than do large species This may be attributed to the greater degree of predation to which the smaller species are exposed

Field mice (*Microtus*) and their allies occur throughout the temperate regions of the world Their labyrinthine runways thread every suitable meadow and field These little mouse paths are not particularly concealed, and, as the mice are active at all hours, they are susceptible to the attacks of a host of enemies Raptores, carnivores, and reptiles all take a colossal toll, and were it not possible for these voles to breed rapidly their numbers would soon decrease To maintain their high populations, these mice produce large families, numbering from four to nine, and one litter succeeds another without letup A captive field mouse was observed by Bailey[14] to produce 17 consecutive litters of young within a year and then she showed no signs of being near the end of the breeding season, while several generations of her young had been busily following her example, one of them producing 13 families before she was a year old Although long study of this group by the writer convinces him that such a situation seldom obtains in nature, the field mouse is undoubtedly the most prolific mammal in the world

Shrews and deer mice (*Peromyscus*) are widely distributed and occur in a variety of habitats, hence they are preyed upon by numerous enemies They bear large families and have at least three litters a year On the other hand, although ground squirrels (*Citellus*) have a host of predators ever ready to destroy them, their subterranean habits protect them from

many foes and the need for a high reproductive potential is not so great It is customary for these squirrels to produce but a single litter in a season, usually numbering five or six Pocket gophers spend the greater share of their lives in their underground tunnels and most produce but one brood a year Where abundant food is available over a long season, such as in the irrigated alfalfa fields of the West, two or even three families may be produced in a year [16]

Rodents are by no means all prolific breeders Some of the kangaroo rats reproduce at a slow rate These rodents have from one to three young, and the majority of females produce two This, taken in connection with the protracted breeding season and lack of sure evidence of the production of two broods a year, gives a surprisingly low rate of reproduction, indicating relative freedom from inimical factors Moles and bats have few enemies and produce but one small litter each year The armature of the porcupine protects it from all but a few predators and as a consequence it produces but one young every year The large size of the beaver is likewise a guaranty against severe predation, and a single litter containing two to four young is produced annually

So far as we now know, all our carnivores, with few exceptions, have but one family each year and the larger of these, as the bear, breeds every other year A second litter, produced in August, has been observed for the little spotted skunk (*Spilogale putorius*) [17] This is an adjustment to meet the needs of their food supply, for it permits the faster breeding rodents to maintain their numbers in the face of normal predation and acts also to prevent undue increase in the predators to a point where their numbers might threaten the food supply and thus, their very existence

Seals, whales, walruses, and other sea going mammals of large size have few natural enemies save the fierce killer whale in consequence seals produce but one pup annually and whales usually bring forth a single calf at 2 year intervals

The nine banded armadillo always gives birth to four young at a time These quadruplets are invariably all of the same sex in a litter and are nearly identical even in their finest anatomical details, such as the numbers and arrangements of the plates and scales in the armor and the numbers of hairs in a given area of the skin [18] This unique polyembryonic condition is apparently characteristic of the nine-banded armadillo, for Sanborn[19] reports one and three young respectively in the three banded armadillo (*Tolypeutes*) and the six banded armadillo (*Euphractus*) The armadillo at birth is very large for the size of the parent and well developed, with a tough leathery skin

The young of ground squirrels which produce a single litter grow rather slowly Edge[20] observed that the Douglas ground squirrels (*Otospermophilus*) remain in their natal chamber for 8 weeks, the young of the Columbia ground squirrel seldom emerge above the ground before their third or fourth week [21] Chipmunks may produce two litters in a season but the young grow slowly, while woodchucks reach their fifth week before venturing into the outer world

Transportation of Young The young are carried by their parent in various ways (Fig 58) When the breeding chambers of small mammals are disturbed, the mother often dashes off with the young clinging to her teats Most young of murine species exhibit this trait A nursing deer mouse or rat, frightened from her nest will drag off the youngsters without ceremony, but it is usual for one or more to be lost during the precipitous flight If their parent is disturbed and leaves the nest, young pine mice grasp the teats with such determination that they may be lifted bodily in the air and still retain their hold One might expect this firm attachment to have considerable survival value, for it would lead to the escape of both the mother and her brood On the other hand the hampered mother might easily fall prey to an enemy

Individual young are carried by rodent mothers in their mouth the belly held firmly by the lips and teeth while the

FIG 58 —The mother carries her young in various ways *A* spider monkey *B* red bat *C* two-toed sloth *D* giant anteater *E* red squirrel *F*, raccoon *G* pine mouse

youngster curls its head and tail on either side of her face to secure a satisfactory purchase, out of harm's way, and thus lessen her burden. Members of the cat and dog tribe carry their young, when the need arises, by the loose skin of the back of the neck. Bears may occasionally take the entire head of their cubs into their cavernous jaws, yet they hold the young so gently that no harm results even though the cubs are transported a considerable distance in this manner. The polar bear cub grasps its mother's tail when danger threatens and is towed to safety. Shrews (*Crocidura*) have evolved a unique manner of transporting their young to safety. When the nest is disturbed, the young grasp the mother or one another by the fur of the rump and are transported off from danger in a veritable chain.[22]

The young of the swiftly moving ruminants are able to follow the parent about shortly after birth. The coypu (*Myocastor*) is said to carry her young on her back as she swims while others join alongside.[23]

Some bats carry their young with them on the nightly hunting trips. The young, occasionally numbering four, as in the case of the red bat, cling tightly to the teats and fur with their tiny recurved milk teeth while the parent performs her complex aerial evolutions. The mother's prowess in transporting these young will seem to us even more remarkable when we realize that their combined weight may exceed that of the parent body.

The Virginia opossum, like many other marsupials, possesses a pouch (marsupium) in which the young are transported until they are more than 2 months old. The opening of this pouch is supplied with muscles which may all but close the outlet, thus providing a warm retreat for the undeveloped young. Even when the young are as large as mice and have made exploratory trips from the pouch, they return to this haven if danger threatens. Not all marsupials have a pouch and the young must be transported in another manner. Indeed we may find that in the same genus some species have retained

this pouch and others (*Didelphys crassicaudata*) have lost the family badge and must accommodate the young on their well furred backs. The little murine opossum (*Marmosa*) is not provided with a marsupium, the young clinging to the back of their parent when transported. The young of other opossums are carried in a similar manner (Fig. 59).

FIG. 59. An opossum carries her family. The young are carried within the pouch for nearly two months, then clamber on the back of the mother for transportation. (*Photograph by C. W. Schwartz.*)

Recognition of Young. In gregarious species, where the animals form great herds during the breeding season, it is quite remarkable how the mother can recognize her young among the thousands of others. The female fur seal accomplishes this by ear, recognizing the bleat of her young though thousands may be calling at once. After spending a day or two in the sea, where she has been to wash and feed, the mother returns to shore, feeling her way to the spot where she thinks her pup

should be. Before entering the swarm of social young ones she calls out, just as a sheep does for its lamb, and after a bit the young one answers, whereupon the mother strikes out toward the position from which it replies. If the young is asleep and gives no answer, the mother barks or sleeps, calling at intervals until successful.[24] Harp seals exhibit an uncanny knack in locating their young after a day of fishing. Returning to the ice sheet in the evening, the mother finds her proper hole and crying young among many thousands, even though the particular floe may have drifted several miles since morning and the young seals been shifted about by the sealers during the day.[25]

The Nursing Period. Considerable variation in the duration of lactation is evident among different mammals. Young which are produced in an advanced stage require little milk and are soon weaned. Young hares nurse but a short time and may eat solid food within a few days of birth. The incisors of the porcupine have erupted at birth, and it is but a matter of a week or less before the young animal is independent of the mother.[26] The prolific field mouse weans her youngsters on the tenth day and before another 2 weeks have elapsed she is suckling a successive litter. The young of the agouti are well developed when born and attempt to nurse before the umbilical cord has been severed. Enders[27] reports that they nibble leaves within an hour after birth and are soon independent of the mother.

Although young fur seals suckle a matter of 6 or 8 weeks and then only at 2- or 3-day intervals,[28] some pinnipeds have a protracted nursing period. According to Scammon[29] the Steller sea lion is said to lactate almost to the date of birth of the succeeding young (that is to say, more than a year). The walrus is said to suckle her young for nearly 2 years.[30] This long nursing period appears to be quite necessary, the young being unable to dig their chief food, mussels, from the mud until their tusks are 3 or 4 inches long, a length which is not acquired until the animals have reached the age of 2 years.

The right whale nurses for about 12 months, although the lactating period in the blue whale lasts but 7 months [31] According to Barbour[32] a captive manatee calf nursed for 18 months

Rate of Growth Many factors contribute toward the rate of growth The ultimate size attained by the animal usually determines its period of infancy Small short lived field mice probably do not survive longer than 1½ years,[33] but in that period a pair may have produced a hundred young, which in turn have borne several litters These tiny creatures can have no childhood, for the females are capable of breeding, and do breed, when scarcely a month old There is evidence that shrews are similarly precocious, some species living only a year but in that short time providing well for the future of the race by begetting numerous offspring The fox and bobcat, deer, and mink, which have but a single litter annually, grow more slowly and there is a period in their young lives devoted to play

The rule that large animals mature slowly is not without exception The elephant may require 30 years or longer to reach sexual maturity but lives for many years One might assume that whales would likewise experience a prolonged infancy, if for no other reason than the great size they eventually attain Such does not appear to be the situation The great blue whale may total 90 feet, and the young, a quarter as long at birth, nurse for 7 months Before the end of its first year the young whale has more than doubled its length, it reaches a length of 77 feet in its third year, when the females become sexually mature

REPRODUCTIVE BEHAVIOR

Promiscuity All available information suggests that most small mammals are promiscuous Mating is only for the immediate needs Bailey,[34] referring to the field mouse, says

> A female usually accepts the attention of any number of males in rapid succession and shows no choice of individuals favor to young or old or any

regard to relationship, whether sire or brothers or previous offspring There seems to be no moral necessity of life with them other than the most rapid increase possible of individuals of the species The one exception to a complete promiscuity is provided by nature in the slower sexual development of the males, which prevents inbreeding in the litter before the young have scattered, the males not coming to sexual maturity until about the time the first young of the females of the first litter are born

Deer mice, shrews, moles, and bats are likewise promiscuous A female howling monkey which is in oestrous will accept several males and will mate at intervals of several minutes for quite some time, often accepting a different male

Even among promiscuous species, the males often fight savagely among themselves during the breeding season With the onset of this period, males are often taken that have fresh wounds, recent scars, lacerated ears or feet, or abbreviated tails In Eastern United States the first rutting season of the muskrat occurs during late March and early April and during this period the males engage in combat with one another

Polygamy Polygamous males often display wonderful strength and wage desperate battles in establishing their harems Preceding the smaller females to the seraglio grounds, the huge fur seal bulls haul up on the rocky islands of the North Pacific and establish their territory The big males seize one another with their teeth and, clenching their jaws, rip and tear until the combatants are covered with blood and ugly wounds Individuals may be so sorely lacerated that they repair to secluded spots to nurse their wounds or succumb from the beating they have received One large bull has been known to fight at least 50 desperate battles and defeat his assailants every time, and, when the fighting was over and a harem of 15 or 20 females established, he still held forth although frightfully gashed, one eye gouged out, and his body covered with raw, festering wounds

The polygamous elk and others of the deer tribe meet in strenuous battles for possession of the does during the season

of rut The bull s shrill whistle challenges other males and fierce combats occur in the fall Their great rack of new grown antlers are the weapons and so effective are these that the lesser of the combatants may not only be defeated and driven off but may actually be gored to death Not infrequently the antlers of the two are effectively locked and the struggling beasts become progressively weaker, until death intervenes Such battles often terminate fatally for the deer (Fig 35) and instances have been recorded of such occurrences in the elk and moose

Monogamy Monogamous mating among wild animals is exceptional Little exact evidence is at hand that any mam malian species retains a single mate throughout its lifetime Any species of which the male shares in the raising of the family either by bringing food to the young or by assisting the female in sundry ways with her family duties should be considered monogamous Wolves and foxes may be considered in this class for both parents bring food to the cubs Weasels are usually considered to be quarrelsome bloodthirsty ani mals with few redeeming qualities yet they are probably one of a very few species which remain paired for long periods perhaps for life The animals mate in mid-summer but the young are not born until the following spring Even during this long period when neither mating nor the duties of family life draw them together a pair may be found occupying a single den When the young are born the father becomes a devoted provider and may be observed as often as the female parent carrying mice and other small game to the growing youngsters

Segregation of Sexes During the season of reproduction there is a well marked segregation of the sexes among gregarious bats One may find colonies of several hundred little brown bats (*Myotis lucifugus*) during early summer all with but few exceptions being females Merriam[35] has remarked on the remarkable dissociation of the sexes in the silvery haired bat (*Lasionycteris*) In a single summer he killed 85 adult speci mens and but one was a male It is not improbable that the

males of this species resort to caves while the females are raising their young, as Poole[36] observed with *Myotis*

BIBLIOGRAPHY

1) Heape Walter 1930 *Quart Jour Micr Sci* 44
2) Hamlett G W D 1935 *Quart Rev Biol* 10 441
3) Clark Frank H 1936 *Contr Lab Vert Genetics Univ Mich* No 2 1
4) Shaw, William T 1925 *Jour Mammalogy* 6 108
5) Marshall F H A 1922 The Physiology of Reproduction London p 52
6) Baker J R and R M Ranson 1933 *Proc Roy Soc* 113(B) 490-492
7) Hamilton W J Jr 1937 *Jour Agr Res* 54(10) 784-787
8) Hartman Carl G 1923 *Smithsonian Rept for 1921* pp 347 363
9) Guthrie Mary J 1933 *Jour Mammalogy* 14 210
10) Gates William H 1937 *Jour Mammalogy* 18 97-98
11) Hamlett G W D 1932 *Zeit f wissen Zool* 141(1) 141 157
12) King Helen D 1913 *Biol Bull* 24 377 391
13) Svihla Arthur 1932 *Univ Mich Mus Zool Misc Publ* 24 5 39
14) Vorhies Charles T and Walter P Taylor 1933 *Univ Ariz Agr Exp Sta Tech Bull* 49 408
15) Bailey Vernon 1924 *Jour Agr Res* 27(8) 528
16) Dixon Joseph 1929 *Jour Mammalogy* 10 328
17) Gates *op cit* p 240
18) Newman Horatio Hackett 1921 Evolution Genetics and Eugenics Chicago p 62
19) Sanborn Colin Campbell 1930 *Jour Mammalogy* 11 68
20) Edge Elton R 1931 *Jour Mammalogy* 12 199
21) Shaw *op cit* p 112
22) Wahlstrom A 1929 *Zeit f Saugetierkunde* 4 178
23) Mitchell P Chalmers 1921 The Childhood of Animals London p 178
24) Elliot Henry W 1884 The Fisheries and Fishery Industries of the United States Washington Pt C p 90
25) Bartlett Robert A 1927 *Jour Mammalogy* 8 210
26) Struthers Parke H 1928 *Jour Mammalogy* 9 304
27) Enders Robert K 1935 *Bull Mus Comp Zool Harvard Coll* 78(4) 466
28) Elliot *op cit* p 90
29) Scammon Charles M 1874 Marine Mammals of the North western Coast of North America San Francisco p 132
30) Millais J G 1906 The Mammals of Great Britain and Ireland London 3 269
31) Mackintosh N A and J F G Wheeler 1937 *Discovery Reports* 1 257
32) Barbour Thomas 1937 *Jour Mammalogy* 18 107
33) Hamilton W J Jr 1937 *Amer Naturalist* 71 500-507
34) Bailey *op cit* p 529
35) Merriam C Hart 1884 Mammals of the Adirondack Region New York p 190
36) Poole Earl L 1932 *Reading Publ Mus Bull*, 13 15

CHAPTER VIII

THE HOME OF MAMMALS

THE word home has been loosely employed by naturalists Some designate it as the place where the family is raised and parental duties occur, while others consider the home of a species in a more general sense, considering it to be the place where a species passes the greater part of its life Students of geographical distribution consider the home of an animal to be that place which it occupies regularly for a part of the year In this chapter, the word home connotes that area in which the species passes the greatest part of its time or in which a definite attempt is made to establish something approaching permanent quarters It is rather difficult to draw hard and fast rules on this score Hoofed animals, pelagic species, and, to a lesser extent, hares and their allies, to cite a few, make little preparation toward establishing anything approximating permanent quarters On the other hand, beavers, prairie dogs, and many wild mice seldom venture far from their long-established quarters and may often spend their lives on a few acres, returning to their lodges, dens, or nests daily for their entire lifetime

The ability to adapt themselves to their surroundings is best illustrated among mammals in their choice of a home site Few species insist on a stereotyped sort of home, practically every species which constructs a nest or other shelter

may utilize a different building material or choose variable sites depending upon the nature of the country which they inhabit. Red squirrels may be living in what might appear as an ideal situation for a tree nest, yet all their dens will be located beneath the ground. Raccoons, when heavily hunted, often forsake the favored old tree sites which have provided them haven for years and resort to fissures or shallow caves in cliffs and they may even utilize the deserted burrows of woodchucks.

Nomadic creatures, such as cetaceans, seals, and other marine species, make no provision for a home, unless the sheltered bays and barren arctic islands to which they repair during the season of reproduction may be called such.

Most wild members of the dog tribe make little provision against the weather, seeking only what shelter they may find and curling up, the bushy tail resting over the relatively thin furred face. The porcupine, guarded by a thick hide and dense coat, withstands the most severe winter weather, afforded protection only by the trunk of the tree on which it is perched. Tree bats (*Lasiurus*) hang suspended from limbs, often not protected from the sun by the protective shade of leaves. None of the hoofed animals provide a permanent home site for themselves, resting where fatigue impels them and moving on as hunger demands. As an exception to this, we may look to the desert big horn sheep. The extreme heat of the desert summer, where temperatures may rise to 125°F., has made cave dwellers of these sheep, and almost every cave and crevasse in the rocks in the good sheep country of Mexico is a foot deep in dung. There the sheep lie during the hot hours of the day, waiting for the terrible heat to subside and the desert to cool. Bones and rotting horns about every cave show that the sheep often die in their beds and that predators may occasionally catch them when they use their cool dark caves instead of bedding down on a lofty windswept point, as they habitually do during the winter.[1]

TEMPORARY SHELTERS

While many mammals make little attempt to provide a permanent home, some species do construct a temporary residence which they may utilize for a single day or several at most. Such homes may be nothing more than the form utilized by cottontails. A clump of grass, brush pile, brier patch, or tree base is selected and the animal sits motionless in this retreat, seldom moving unless disturbed. So secure is this simple lair that the rabbit, undisturbed by severe weather, will permit snow to cover it, this providing a yet safer retreat.

Small tropical opossums (*Marmosa*) sometimes remain curled within a dead banana leaf during the day but move on at night, seldom returning to the protection of the same leaf a second time.

Field mice often construct a hole scarcely large enough to admit their bodies and back into these to spend their resting hours rather than utilize the extensive underground runways and grass nests which the species usually makes.

Though pelagic species can have no real home, the sea otter has adopted an ingenious method which prevents individuals from drifting away from the main body. As darkness approaches, the herd swims toward a kelp bed, where they roll and twist about in the weed in such a way as to wrap several strands of kelp around them. Individuals of the herd sleep very close together, so that their appearance is that of a very compact mass. The same kelp bed is used night after night so long as they stay in its vicinity.[2]

American monkeys merely resort to some favorite tree as night approaches, making no attempt to construct a platform or even a temporary shelter such as certain African monkeys and apes often do.

Little is known of the habits of the marsh rabbits (*Sylvilagus palustris*) but there is evidence in the burned-over marshes that in summer the rabbits gather cut rushes and make plat-

forms on which to sit in places not normally overflowed by the tides

Unlike its congener the cottontail, the hare is said not to make a tunnel or resort to a burrow, yet MacLulich submits testimony which shows that the varying hare will construct a burrow of its own or at least utilize that made by some other animal Our Western jack rabbits are not known to make any home, resorting only to a clump of cactus or such shelter as will give them protection from the torrid sun The young are deposited directly on the desert floor, no attempt being made to provide them with any shelter other than shade for their advanced stage at birth precludes the necessity of any elaborate shelter

Fig 60—This palm frond (*Geonoma*) of Panama has been cut by the leaf nosed bat (*Artibeus watsoni*) The cut section falls down to make a temporary shelter for the bats during the day (*From My Tropical Air Castle by Dr Frank M Chapman courtesy of D Appleton-Century Co*)

Usually bats as we have seen, repair to some secluded nook or cranny amid a clump of leaves or under loose bark but in tropical America certain bats (*Uroderma bilobatum*) make a shady retreat In Panama these bats select a palm with great stiff palmate fronds and, by nipping the ridges of the plications on the under side of the leaf make it weak enough for the distal portion to droop sharply downward At the bitten spots the bats are able to gain an easy foothold and

here they cling, sometimes twenty or more animals utilizing a single frond The bats are thus protected from the brilliant sun and torrential showers common to Panama [4] Another species (*Artibeus watsoni*) has a similar habit Chapman[5] found this species would cut the vanes of a palm leaf (*Geonoma*) diag onally to the mid rib, so that their terminal portions drooped downward to form a tent like shelter (Fig 60)

In addition to the large lodge where the muskrats spend much of their time, smaller huts, sufficiently large to contain a single animal, are used as feeding stations There may be several of these if the pond is large These small structures are scarcely a foot high, a single tunnel leading from them to the pond bottom, where succulent roots are obtained

Feeding platforms with plunge holes leading into the sphagnum or peat are constructed by the round tailed musk rat (*Neofiber*) and are further utilized by rice rats [6]

Squirrels, mice, and other small mammals make simple but substantial nests of leaves, grasses, or other available mate rial These are cleverly constructed to harbor the occupants safe from the elements Such structures are usually temporary and may be used only for family duties, but others may be more elaborate and serve the builder for long periods

The small ground-dwelling voles and lemmings construct compact nests of grasses semi globular in shape These are usually prepared at the base or in a clump of grass, in a slight depression in the ground or well concealed in an underground chamber Field mice often construct their nests directly on the ground where there is little cover, and as a result these chambers are exposed to heavy rains and snows The nests suffer little from the elements, however, for the clever con struction has been made to withstand these hazards, and after heavy and prolonged rainstorms, the occupied nests are invariably warm and dry within During the winter the ground nests are somewhat more bulky, and the heat from the occupants within will cause a warm air current to arise, melting the snow above to form a regular chimney (Fig 61)

The little tree mouse (*Phenacomys longicaudus*) of the southern Pacific Coast is the only vole which habitually makes its home in trees. It lives chiefly in the forested areas of Douglas and grand firs, where it constructs sizable nests, seldom venturing to the ground except to reach some other tree. This little reddish loog-tailed mouse feeds almost exclusively on the fleshy portion of fir needles, utilizing the fibrous patrs

Fig. 61.—The winter quarters of a field mouse. These grass nests are so firmly woven of dead grass that the interior remains dry during prolonged storms. The heat of the occupant has melted the snow about this nest

to coostruct the bulky nests. These nests were found by Howell[7] at an average elevation of 30 feet, but it is probable that the deose foliage hid many nests at higher elevatioos The nests may be situated on a limb directly against the trunk, although the majority which have been studied have been some distance out on the limbs. The females build the larger nests, some attaining a size of 3 feet in horizontal diameter and 2 or 3 feet in the vertical. Occasionally abandoned squirrel nests are utilized and added to. Usually a single chamber is formed, near the top, but as the nest continues to increase in

size with the daily accumulation of partially consumed needles, the animal makes a second chamber for sleeping quarters or for toilet purposes During the night the mice are busily engaged in collecting a supply of twigs, which are piled upon the nest for consumption during the day

The compact strong nests of the fox squirrel have been well described by Stoddard [8] These nests are round or oval in shape tightly woven of freshly cut oak or other tough twigs Within this strong outer shell there is a thick compact wall of large leaves, evidently pressed into shape while damp, making a smooth tough lining capable of resisting wind, cold, and rain Within this the true nesting quarters are composed of shredded soft inner bark and leaves The single entrance is just large enough to admit the owner, and the surrounding loose fiber almost occludes this opening These tough winter nests which are made for the reception of the young in late winter are very different from the loose hastily constructed leaf nests of summer and may resist wind and storms for years whereas the latter may be destroyed by a hard blow Gray squirrels make similar nests, substantially built to conceal the March born young

The red squirrel is an adaptable species and will resort to an abandoned woodpecker cavity or a hole in the ground or build a bulky nest in the crotch or branch of a tree Usually the nest differs little from that of other squirrels, being constructed of the material nearest at hand In stands of white pine a loose platform of sticks is usually gathered to support the home, but in arborvitae spruce, and tangles of grape this platform is dispensed with The nest is frequently made of shredded bark, cedar and grape are highly prized and if these are available the squirrel will use no other material The nests are often quite bulky, sometimes almost completely filling a 12-quart pail but the cavity is large enough only to admit the single owner Occasionally a deserted hawk or crow nest will be utilized, merely by the addition of a capping of bark leaves, or grasses

Nests of the golden harvest mouse (*Reithrodontomys*) are generally built several feet from the ground, concealed in tangled masses of the rank marsh vegetation. The nest, very compact and about the size of a baseball, is composed of the shredded leaves of various marsh grasses and usually shelters a pair of these dainty rodents.[9]

The star-nosed mole, often semi-aquatic, makes a bulky nest beneath a log, in a chamber of its extensive tunnels, or in a slight rise of ground. If the habitat is a swamp or marshy area, the animal takes pains to select a site well above the high-water line by placing the nest in some natural elevation.[10] The nest, as are most others, is composed of the material nearest at hand.

Our true rabbits (*Sylvilagus*) excavate a shallow depression, which the female carefully lines with fur plucked from her breast and belly. During the day the nest is carefully concealed, covered with grass, leaves, or such matter as is at hand, and the young are unattended in this retreat. During the early evening the cottontail returns to suckle the young, but before leaving them she again carefully conceals the nest so that little or no trace of its presence can be noted. So skillfully is this feat accomplished that the writer daily worked about such a nest located in his garden, often pulling sprouting weeds within a foot of it, but never was apprised of its existence until a dog discovered the retreat and scattered the fur lining. Rarely a rabbit will utilize a deserted woodchuck burrow for its family duties, but such burrows are usually resorted to during the winter months only.

constructed near the ground level, but in dry seasons the permanent quarters may be located well beneath the level of the terrain, often a foot or more. Western ground squirrels, during the dry season, will prepare temporary burrows to serve as a retreat, but these are made merely to serve as a shelter near a suitable food supply. Generally the animals are averse to wet

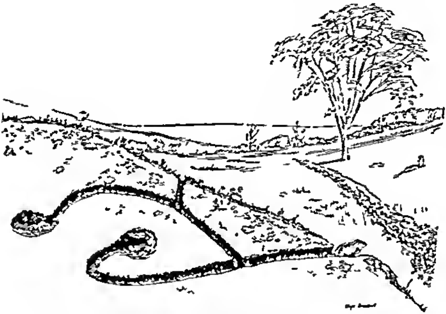


FIG. 62.—The woodchuck and his home. A cross section through a hillside, showing the construction of the burrows and chambers. A characteristic of the woodchuck burrow is the fresh pile of dirt and stones at the entrance.

ground and make their burrows on sloping or well-drained soils (Fig. 62).

The Florida deer mouse (*Peromyscus polionotus*) constructs a simple oblique shaft in the sandy soil, the burrow descending to a depth of a foot, where the nest is constructed. From this chamber another tunnel ascends obliquely nearly to the surface. It is said to be an emergency exit, the mouse pushing through the thin cap of soil when routed by a snake. The fresh burrows are characterized by a mound of dirt at the burrow entrance, this amounting to several cupfuls.[11]

Many ground squirrels make elaborate subterranean chambers which are used year after year each season seeing additions to and repairs on these long-established home sites None are more remarkable than the elaborate tunnels of Texas prairie dogs described by Merriam [12] The mouth of the burrow opens in the middle of a mound which is 1 foot or more in height and 3 or 4 feet in diameter As the mound

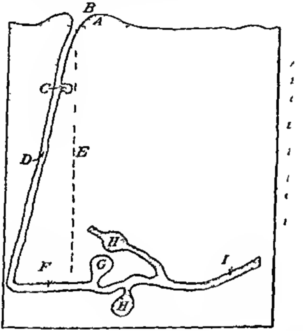


Fig 63 A prairie dog burrow (After Merriam)

increases with age it grows larger finally attaining a diameter of 8 or 10 feet The inside of the crater shaped mound is molded and formed by the nose of the animal which leaves characteristic marks This elevated mound is a safeguard against sudden downpours and effectively prevents the tunnel from being flooded The abrupt holes follow a precipitous course usually straight down and often to a depth of more than 14 feet when they turn at right angles and continue horizontally usually rising slightly at the end (Fig 63)

From this lateral are short branches terminating in a rounded chamber in which a large nest of dried grasses is formed A few feet within the hurrow a short side passage may he found, where the animals may rest and turn, to hark and scold at the intruder or from which they may return cautiously to the entrance to survey their domain

Occasionally the mounds are not sufficiently high to prevent the inrush of water on irrigated lands or during sudden down pours, and the prairie dogs provide a unique avenue of escape for use when they are threatened with drowning Shallow hurrows, with laterals not deeper than 3½ feet below the ground level, are provided with additional laterals which teach to within 6 inches of the surface As the water inundates the hurrow, the rodents repair to these ascending laterals where they can remain in comparative safety for several hours or longer, for the inrush of water causes an air pocket to form in the top of the lateral which lasts until the air can escape through the earth Eventually the surface of the ground becomes sufficiently moistened so that the air has little tend ency to escape [11] This appears to be a most logical explanation of why few prairie dogs are drowned even though towns are known to have been completely under water for several hours at different times during the season

The characteristic mounds of the kangaroo rats (*Dipodomys*) are familiar to many residents of Southwestern United States These mounds, usually rather low and with several openings, are often seen in the savannah of Western states where the climate is arid The mounds are usually not high but the extent is determined hy the character of the soil The mounds (Fig 64) are conspicuous largely because of the absence of vegetation, which is removed by the kangaroo rats often for a distance of 30 or more feet from the mound The Western traveler is often amazed to learn that so small an animal, and often only one ar that, is capable of making such a large mound with often a dozen entrances, some much larger than necessary to admit the rodent responsible for them

Bailey[14] remarks that a fair sized mound may measure 10 by 12 feet in extent and 18 inches high above the ground level and about the same depth below the surface Those of some age may have a complex system of chambers, while others recently constructed, are relatively simple Bailey further states

> Each mound is a well-developed structure with numerous rooms or cavities for nests storerooms feeding places halls stairways and winding tunnels

Within this intricate system of burrows are numerous side pockets for the storage of seeds and other edibles Since in the habitat selected by these kangaroo rats there may be no rain for months, it is obvious that they must practice storage when seeds of various sorts are available As a result the chambers, when excavated, reveal great hordes of food, stored for times of adversity when food above ground is simply not available

Leading from these denuded mounds are well-defined trails, well marked through the sparse growth of the plains These lead to smaller mounds or simple tunnels in the soil and act as a place of refuge when the kangaroo rat is alarmed and some distance from its home chambers No mammal burrows other than the mounds of prairie dogs are more familiar to the Western ranchman than the workings of this rodent

The burrows of pocket mice (*Perognathus lordi*) are rather extensive for such diminutive creatures In the semi-arid country of eastern Washington the burrows are difficult to explore because of their depth and the powdery nature of the soil The burrow may descend more than 6 feet to the nests, which are about the size of a baseball and composed of fine weed twigs, seed husks, and bits of dried grass Scheffer[15] remarks that the mice, in order to reach such a depth by easy grades, constructs a spiral burrow, which has in its course two or three hairpin loops, all within a comparatively short horizontal radius A single main tunnel is found in the deeper part of the system, but nearer the surface there may be two or more branches that each terminate in an entrance

Many burrowing mammals, particularly the smaller fossorial rodents, prepare a short lateral branch just within the entrance, which culminates in an enlarged chamber When the burrow is disturbed, the animal may take refuge in this chamber, plugging it with dirt from within to escape detection

It is not uncommon for burrowing mammals, particularly the smaller species, to close their burrows during the period

when they are inactive Deer mice, pocket mice, kangaroo rats jumping mice, and ground squirrels all are known to exhibit this trait The purpose may serve two functions to close the burrow from the heat of the day and to protect the inhabitant from marauding snakes and other predators The burrow is so carefully and effectively plugged that human observers can seldom recognize the site as a burrow entrance

Porcupines occupy the fissures in rocky cliffs, where they congregate during the winter season The larger dens may house a number of animals, of mixed sexes, while small cracks or shallow retreats in the rocks are used by single females as farrowing dens It is comparatively easy to locate these dens by the large number of damaged trees in the vicinity Usually the porcupine shows a marked preference for den sites which have a southeasterly or southwesterly exposure Lacking a rocky denning site, the porcupine will select a stump or hollow log

HOUSES AND LODGES

The Beaver Lodge No mammal residence has excited more wonder and interest than the lodge made by the beaver Whether it be large or small, on a relatively dry sphagnum bog or supported by a foundation of sticks and mud in 6 or more feet of water, the lodge never fails to create admiration The site selected for the lodge may be far removed from shore but it is more often encountered in water not exceeding 5 or 6 feet in depth (Fig 54) Again it may be constructed in a clump of low growing shrubs, such as willow or even on a slight prominence of land arising above the water level If in the latter situation the first concern of the beaver is to prepare a proper entrance or hole—usually but one—leading through the muck or solid land to the water As food is brought to this site the branches are peeled the bark eaten and the stripped limbs laid or pushed about the plunge hole If the site of the lodge has been selected in water several feet

deep, the sticks are allowed to settle and become water logged, or larger pieces are brought to such a site where they are slowly added to until a mass is formed well above the water level As this level is reached more material is added, until a circular wall is completed, when finally the narrowing top is capped with additional twigs and discarded limbs As cold weather approaches, the beaver brings in its fore paws great armfuls of mud and sod, decayed vegetation, and the like, to chink and plaster the firmly interlocked twig walls This accomplished, it has but to wait for freezing weather, when the cold will make the structure an impenetrable fortress against even the mighty paws of the bear If the residence is maintained, additional twigs are added annually, until finally the walls may be settled and thick, more than 2 feet through about the base

The inside of the lodge has a single chamber slightly above the level of the water The floor of one lodge which the writer examined in the Adirondacks sloped slightly to the plunge hole, its highest point about 4 inches above the water level In large houses the room may be several feet high and have as much floor space as the interior of a coupe Bailey[16] states that, if more room is needed, the beavers hollow out the walls, cut off the sticks, and dig back the earth to make room in any desired direction, the massive walls of large lodges allowing for any inside change found necessary A dozen beavers have been known to inhabit a single lodge, although the usual number is much smaller, seldom exceeding seven or eight The heat from the beavers may make the lodge uncomfortably warm for these thick robed animals, and ventilation then becomes necessary Even though the lodge, seen from the outside, may appear too tight for the occupants to get air, particularly when the house is covered with snow and ice the occupants never fail to get sufficient fresh air At such a season, the warm air circulates up through the relatively thin dome, warm enough to melt the snow and form an inverted cone through this covering Even in freezing weather such a

spot on the lodge is said to feel warm and damp to the hand There may even be a small hole through the top of the lodge where air may filter in or out [17]

The floor of the lodge serves as a bed and dinner table Here the beaver feeds, repairing to its storehouse of under water limbs, removing a twig and carrying it to the lodge The bark is removed, the finer remains are utilized for a nest, and the larger or coarser twigs are carried to the dam to reinforce this structure or are used to patch the lodge as occasion necessitates The refuse may be used to raise the floor if the water rises Vernon Bailey says that the beaver, when leaving the lodge, rarely comes to the surface near by and may often swim 10 or 20 rods before coming to the surface to look around if frightened, it may go a half mile or more under water and then come up under cover of the bank or shore vegetation or enter another house or bank burrow

Usually the work on the lodge is done at night, except in remote regions little disturbed by man, and even in such situations beavers seldom trouble to repair or add to their dams or houses during the daylight, preferring the early evening and dark hours It is a rare autumn pleasure to see these big rodents climb to the edge of the house and march erect to the walls, a great mass of dripping mud and debris in their fore paws, and chink the lodge in preparation for the rigorous months ahead

shape, mud and detritus are added, all lending further strength and support to the structure As the rising dam halts the stream flow a pond is formed, and as the water level increases the structure is added to, until it can safely withstand the spring freshets and the huffeting of spring breakups

Some dams attain truly remarkable dimensions, reaching a height of 12 feet and a length of several hundred feet On the other hand, the structure may be less than a foot high, several feet long, and composed entirely of mud and rather small twigs, sufficient only to stanch the flow of sluggish streams in their shallower portions

Beaver Canals The long and often elaborate beaver canals are constructed for the purpose of furnishing a suitable and accessible highway over which the beaver may transport food to the pond and storage quarters These canals are usually absent or of short length in the forested regions of North eastern America but often reach large dimensions in Western America Often the canal is wide and deep enough to accomodate a single animal only, but the Montana beaver canal described by Berry[15] is without parallel This canal had a length of 1,145 feet and was wide enough to float a canoe, its sides being well banked to retain the flow

The Muskrat House All who have lived near a swamp or marsh in Northeastern America are familiar with the dome-shaped winter lodge of the muskrat (Fig 65) These lodges serve as winter quarters for the animals and provide a safe retreat for the female during the season of reproduction They vary in shape throughout North America, usually being more or less dome-like in appearance although the muskrat houses of the Maryland marshes are characteristically flat topped Muskrats do not always construct lodges, sometimes preferring to burrow into a convenient bank, where a dry nest chamber is constructed well above the level of high water Even in situations where they have every opportunity to do so, as in Arizona and California, the animals apparently never construct lodges Along much of the coastal waters of

Northeastern United States the muskrats likewise appear content to resort to banks lining the tidewater creeks

The houses vary in size, some of the largest examined by the writer on the extensive cattail marshes of central New York were 10 feet in diameter and 4 feet high, but the structure is usually much smaller, often scarcely exceeding a bushel crate in size In choosing a site for the house, the animals select a

Fig 65—A muskrat house and feeding shelter Muskrats often build these smaller shelters where a single individual will repair to feast The larger house may accommodate six or more animals

mass of flag, a group of willow sprouts, or a mud and vegetation-choked pool More often than not the lodge is situated in a relatively dry spot, so that the muskrats must dig a channel well below the bottom of the house to reach water If the house is established in a foot or more of water in an open pond, sedges, cattails, pondweeds, and other coarse vegetation, often long dead are brought to the site The water soaked condition renders this material more or less immovable as it continues to pile up The muskrat prepares a plunge

hole through the mass to the water below As more material is added and as it continues to settle, the animals pull away a sufficient amount of the filling to make a satisfactory living room within The walls of coarse material are finally wadded and plastered effectually by mud and water-soaked small vegetation A single chamber, occasionally containing several alcoves slightly partitioned from one another, serves the rats with feeding and sleeping quarters Usually there is a single plunge hole but upon occasion there may be two holes It is seldom the largest houses provide quarters for more than 5 or 6 rats but the writer positively knows of one enormous lodge from which 14 rats were taken in the course of several days

Not many years ago the high price received for muskrat pelts tempted boys to collect these animals in every possible manner A hockey stick was thrust through the walls of the lodge, and, as the frightened muskrats swam away, a slender spear was thrust through the ice, impaling the animal It was noticeable that even on the coldest days, little difficulty was experienced in breaking into the house on the south side and this led to the belief that the house had thinner walls on this side allowing for some ventilation

The round tailed muskrat (*Neofiber*) constructs a lodge similar to that of its larger cousin These huts are anchored in a tuft of large plants or on a more solid foundation formed by a clump of bushes The nests may be quite large for its occupant measuring 2 or 3 feet across the base and 12 to 18 inches high The chamber is rather small and permits the animal only to turn about comfortably The two water filled exits lead into the bog below

Wood rat Nests While the great heaps of sticks and trash which characterize the home of wood rats are usually referred to as nests these structures might properly be classed as lodges Their structure and complexity are at times even more varied than the beaver house Wood rats build their lodges in a tree, about a large stump or in a cave In the last case

the nest is merely an open structure composed of shredded bark

The dusky-footed wood rat (*Neotoma fuscipes*) of Oregon builds large structures, often of a rather elaborate nature These structures have been studied by English,[19] who describes

Fig 66—*A large tree nest of the dusky-footed wood rat (Neotoma fuscipes)* While these wood rats make large brush lodges on the ground, they often resort to trees, possibly to escape *terrestrial enemies (Photograph by Dr P F English)*

them as being built in rather inaccessible places, such as thorny thickets of rose briar, hawthorn, blackberry, and thick brush Large nests may be divided into as many as five compartments, these being used, as nursery, living room, and storage chambers, while still another chamber is used for the deposit of dung The inner compartments are connected by a

series of runways, making communication simple The cham bers have exits to the outside and, less often, a short runway leads into the ground beneath the nest, ostensibly as a place of retreat when the nest is disturbed The rats may construct a bulky nest in a near-by tree (Fig 66), scarcely less simple than the ground nest, to which they resort at different times Occasionally these attain tremendous proportions Where the large outer limbs of adjacent live oaks cross one another, the rats draw in the smaller branches to make a substantial platform and on this the bulky nests are constructed These nests may attain a height of 5 feet or more and the base an area of 9 or 10 square feet Such nests may require two seasons to build before attaining such large proportions

BIBLIOGRAPHY

1) O Conner Jack 1938 *Field and Stream* January p 78
2) Fisher Edna M 1939 *Jour Mammalogy* 20 34
3) Tomkins Ivan R 1935 *Jour Mammalogy* 16 202
4) Barbour Thomas 1932 *Quart Rev Biol* 307
5) Chapman Frank M 1932 *Natural History* 555
6) Harper Francis 1927 *Proc Boston Soc Nat Hist* 363
7) Howell A Brazier 1926 *N Amer Fauna* 48 44–45
8) Stoddard H L 1920 *Jour Mammalogy* 1 122 123
9) Svihla Ruth Dowell 1930 *Jour Mammalogy* 11 53
10) Hamilton W J Jr 1931 *Jour Mammalogy* 12 347
11) Sumner F B and J J Karol 1929 *Jour Mammalogy* 10 214–215
12) Merr am C Hart 1902 *Yearbook U S Dept Agr for 1901* pp 260–261
13) Foster B E 1924 *Jour Mammalogy* 5 267
14) Bailey Vernon 1931 *N Amer Fauna* 53 252
15) Scheffer Theo H 1938 *U S Dept Agr Tech Bull* 608 9
16) Bailey Vernon 1926 *Jour Mammalogy* 7 42
17) Salvesen Harold Keith 1934 *Jour Mammalogy* 15 323
18) Berry S Stillman 1923 *Jour Mammalogy* 4 102
19) Engl sh Pennoyer F 1923 *Jour Mammalogy* 4 2

CHAPTER IX

HIBERNATION

Hibernation involves an inactive state in which metabolism is greatly lowered, resulting in body temperatures slightly higher than that of the surroundings It usually occurs among certain mammals during the colder months of the year Hibernation has been incorrectly termed *Winterschlaf*, for it may occur in summer Apparently, hibernation has nothing to do with the ordinary sleep of winter, for the insensibility is far greater than in ordinary sleep Hibernation is common in many invertebrates, such as snails and various arthropods In the Northern states practically all poikilothermous vertebrates hibernate, for they are without a heat regulating mechanism Birds are homoiothermic, as are mammals, although the temperature of the latter may vary considerably Recent studies[1,2] indicate variable temperatures in active ground squirrels and woodchucks The ordinary summer sleep of bats approximates hibernation, for a few moments after they have fallen asleep respiration is retarded and there occurs a decided drop in temperature

Mammals That Hibernate Except the bats, most mammals that hibernate are partly fossorial, spending many of their active hours below ground, although the bear, skunk, and raccoon are exceptions Even these do not exhibit the characteristics of true hibernation, for their body temperatures do not appreciably drop and their sleep is intermittent

The most pronounced North American hibernators are the ground squirrels (*Citellus*), woodchucks, bats, and jumping mice. The skunk, raccoon, badger, and opossum become torpid for several weeks, or occasionally for a much longer period, but often venture forth during mild periods during the winter. Bears do not hibernate in the true sense of the word, for they retain a high temperature during long periods of drowsy inactivity. Chipmunks (*Tamias*) become dormant but are active during warm weather in the winter. Tree squirrels may be inactive for a period of several days at a time but do not hibernate. Even the non-migratory bats of our Northern states, which are found in great clusters on the walls and ceilings of caves during winter, are easily awakened and fly about if disturbed.

THEORIES OF HIBERNATION

Theories of hibernation[2-4] indicate only that great diversity of opinion prevails regarding the cause of this interesting condition and that much of the opinion has been based upon insufficient data.

Temperatures. Many have considered a low temperature necessary for hibernation.[5] Moderate cold is favorable for hibernation, but the onset of sudden severe cold may irritate and kill the animal.[6] Wade[7] observed that some ground squirrels hibernated at 21°C., although it was observed that optimum hibernating temperatures for captive ground squirrels appear to be about 5 to 12°C. Eastern woodchucks often hibernate before the first killing frost[8] while chipmunks seldom repair to their winter quarters before early November. Bats are often seen flying about in November and, less often, in early December in New York State. Jumping mice (*Napaeozapus*) have been recorded moving about in mid-winter. Low temperatures appear to be the exciting cause of hibernation in the skunk, notably the females.[9] Early November night temperatures of 15 to 25°F. induce skunks to remain denned for a short duration. Usually by mid-December, in the

North, most of the females have hibernated, but it is not uncommon for the males to remain more or less active throughout the winter

Food Numerous investigators[10 11 12] have considered the lack of food a contributing cause of hibernation It is an obvious cause among the insectivorous bats, which must migrate, hibernate, or starve with the advent of severe weather Woodchucks, on the other hand, hibernate at the very period when early fall rains have given new life to the meadows and fields are lush with sprouting greens [13] Surely lack of food cannot be a contributing cause to the long sleep of the woodchuck Jumping mice have food habits similar to deer mice during the summer, and there is no reason to suspect that their winter food habits would be different were they to remain active Weed seeds, grasses, and ripening small fruits are abundant after jumping mice hibernate, so that food cannot be the primary cause of winter sleep with these animals

Dry food apparently induces hibernation, for ground squirrels retire to their underground shafts as grain ripens and pastures become dry Temporary influences such as hot winds, which deprive the vegetation of moisture for the animal s food, hasten aestivation, which in the western ground squirrels is similar to hibernation

Obesity Whatever the true cause of hibernation in mammals, obesity is a necessity for this death like torpor All of our true hibernators become excessively fat with the approach of fall Those which fail to acquire a sufficiency of fat remain active well into winter In British Columbia spermophiles and marmots retire a month earlier in the lowlands than at the timber line, presumably because in the latter region they have not had time to acquire enough fat, since at the higher altitudes the animals emerge from hibernation later in the spring [14]

The more torpid the animals become, the greater amount of fat guards their bodies Bears become very fat but sleep intermittently and cannot be classed as hibernators while chip-

munks are active at frequent intervals during the winter and hence are not so fat as their western cousins, the spermophiles. A significantly greater amount of hibernation was found in 38 heavy ground squirrels than in 118 light ones, and the greater tendency of fat animals to hibernate has been observed in many animals in other experiments.[15] Jumping mice and woodchucks hibernate only when their bodies are supplied with a thick layer of fat; animals encountered late in the fall or early winter are invariably lacking in this necessary blanket of fat. A third of the weight of bats taken in late fall may be composed of fatty tissue, while fat accounts for one-seventh of the weight of woodchucks.

Confined Air. An autonarcosis theory has been developed by Dubois,[16] who maintains that an excess of carbon dioxide in the blood is a cause of torpor. It is supposed that an accumulation of CO_2 in the blood and tissues of the animal will cause a form of narcosis, illustrated in torpid mammals. Dubois induced typical hibernating sleep by causing active marmots to breathe a mixture of air (42 per cent), CO_2 (45 per cent) and oxygen (12 per cent). Torpid marmots remain dormant when supplied with this mixture. An increase of CO supposedly acts on a nervous center for sleep situated in the mid brain and the hibernating marmot wakes up. It was actually observed by Dubois that CO accumulates in the blood during hibernation in the marmot and decreases again when the animal wakes up. These observations were partly confirmed by Rasmussen[17] but he found no increase in amount of carbon dioxide in the blood of two torpid woodchucks. Apparently confined air does hasten hibernation, for ground squirrels placed in half gallon cans closed tight except for four nail holes hibernated much sooner than check animals in highly perforated cans of similar size.[18]

A comparison of spleens from dormant bats (*Eptesicus*) with those from awakened animals showed that this organ has a very important function in hibernation. In hibernating bats which were killed without being awakened, the spleen was

large, dark, and congested These spleens were filled with red blood corpuscles and the volume exceeded by three and one half times that of the shrunken spleens of awakened bats From this it seems apparent that during dormancy the spleen of the hibernating bat serves as a reservoir for red blood cells Any disturbance of the animal results in a reflex action of the spleen, which pours the red blood cells back into circulation [19]

Further discussion of the many theories advanced for hibernation seems undesirable, for they are concerned chiefly with laboratory animals and are largely based on insufficient data These theories have been summarized by Rasmussen and Johnson, to whom the reader is referred

CHARACTERISTICS OF HIBERNATION

Temperature It has long been observed that the temperature of hibernating mammals, even when not torpid, may be lower than mammals which do not hibernate The temperature may approximate that of the surroundings or even become lower, as has been shown in torpid ground squirrels [20] Extensive records of the thirteen lined ground squirrel (*Citellus tridecemlineatus*) indicate that the temperature of animals long in deep hibernation approaches that of the surroundings within a little less than 1°C [21] One ground squirrel which was almost dead had a temperature of 0 2°C It did not respire for an hour and had a very slow and abnormal awakening An animal with a temperature of 0°C showed very slight breathing for a short time after 22 minutes, but never woke up From these and other records by Johnson of death at low temperatures it would appear that the body cannot endure an internal temperature as low as the freezing point

Hibernating mammals are peculiarly adapted to resist freezing for they almost invariably awaken when there is a sudden drop in the atmospheric temperature to freezing or lower If they remain dormant, as occasionally happens, the animals freeze to death [22]

The temperatures of woodchucks approximate that of their surroundings during hibernation Rasmussen[23] found the temperatures of hibernating animals to range from 6 to 14°C The rectal temperature of a female in deep torpor which was studied by the writer ranged from 8 to 17°C [24] Hibernating skunks do not experience a lowered temperature, neither do bears, for it has been observed that snow falling on their bodies in sub-zero temperatures rapidly melts [25] Hibernating raccoons which the writer has handled felt warm to the touch, although the temperature of the hibernating chamber was well below the freezing point Opossums retain a temperature of 33°C when sleeping for several days in atmospheric temperatures of 2 to 8°C The badger is said to maintain a high temperature during hibernation

The temperatures of bats approximate their cave surroundings, but these remain relatively constant (50 to 60°F) throughout the year in extensive caverns The air in these caves may often contain moisture nearly to the point of saturation The writer has seen the pipistrelle (*Pipistrellus subflavus*) hanging singly from the walls of caves, its fur wet with condensed moisture, appearing in the beam from the flashlight as though covered with fine silvery jewels

Respiration A surprising range in respiration has been found in normal ground squirrels Although the average is 187 inspirations a minute, the inspirations sometimes drop markedly, so that there may be from one to four a minute [26] Inspiration can barely be detected in torpid woodchucks and may occur only at intervals of 4 to 6 minutes Respiration was so low that observation of a torpid jumping mouse (*Napaeozapus*) for 15 minutes showed no indication of abdominal movement [2] Black bears in hibernation at sub-zero temperatures were observed to respire at the rate of four and five times per minute [28] A captive opossum studied by the writer respired 16 times per minute at an air temperature of 21°F The animal was undisturbed and had all the appearance of hibernating, although it had a body temperature of 91 3°F

It has been observed that the respiration of an undisturbed hibernating bat (*Eptesicus*) proceeds intermittently, periods of apnea 3 to 8 minutes long alternating with periods of 3 minutes or less of breathing at the rate of 25 to 50 inhalations per minute After the bat has been thoroughly aroused, it breathes at the rate of 200 respirations a minute and the body temperature has risen from within 2 or 3 degrees of the atmospheric temperature (about 45°F) to over 98°F [79]

Heartbeat Very slow circulation is a characteristic of hibernating mammals In active bats the heartbeat is often too rapid to count, while in semitorpid individuals it is very slow In normal ground squirrels, the heartbeat varies greatly but in those just awakened from normal sleep the range was found to be about 100 to 200 per minute In torpid squirrels the beat was 5 per minute [80] Three days after a jumping mouse (*Napaeozapus*) became torpid, the writer excised a toe and the wound bled freely An animal so treated after being dormant for a period of 2 months showed no bleeding whatsoever [81] Hoy[37] amputated a limb from a torpid ground squirrel and observed only a few drops of blood to ooze from the limb He further remarks on the congested condition of the heart and lungs during hibernation

Death in hibernation appears to be produced by failure of respiration, for experimenters have observed the heart beating in hibernating ground squirrels an hour after the cessation of respiration

Irritability As temperature falls, hibernators become less sensitive to external stimuli It has been shown that ground squirrels with temperatures of 20 to 30°C move in a dazed manner, while a drop to 10°C will elicit only a raised head or other weak response when the squirrels are stimulated If the body temperature falls to a few degrees above 0°C there will be no response to strong stimuli

This lack of response in deeply torpid animals suggests that the bear, raccoon, opossum, and skunk do not actually

hibernate, for they usually all react to a touch of the hand or to a voice, even at zero temperatures

THE HIBERNATION PERIOD

Preparation for Hibernation As previously mentioned, all true hibernators become excessively fat before entrance into the winter torpor A blanket of fat appears an absolute necessity for this condition With the approach of cool weather in the Northern states and the ripening of grain and desiccating winds of the West, the animals become increasingly scarce It has been observed that immediately prior to the hibernation ground squirrels take little food and their alimentary tracts are emptied before torpor overcomes them The period of fasting may occupy a week A similar situation has been noted by the writer with captive woodchucks and jumping mice The disappearance of bats into hibernating quarters follows a period of fasting in which the alimentary canal is thoroughly emptied Bats collected from caves in the winter have empty alimentary tracts but the bladders are often well filled with urine, suggesting that metabolism is not so greatly retarded as one might expect in torpid animals If well fed bats with full stomachs are placed in cold quarters with the approach of the dormant period, they invariably fail to become torpid and usually die within a few days At Kodiak Island, according to guides, the bears gorge themselves with wild cranberries just before hibernation and purge out their intestines thoroughly until they are as clean as though washed with soap and water They then eat the root of some plants that make a tough fibrous plug at the anus This is evacuated soon after hibernation ends [23]

Site Considerable variation of the hibernating site chosen by mammals occurs, even within the species Ground squirrels (*Citellus*) prepare an elaborate chamber underground, at depths varying from one to several feet Chipmunks usually build a nest of leaves below stumps, although the Western striped chipmunk (*Eutamias*) prepare nests in large fir stumps

several feet above the ground level Woodchucks, abundant in the fields and meadows during late summer, repair to near-by woods, where they make a nest of leaves and grass well below the frost level Raccoons select a hollow tree, log, or cliff or may utilize the unused den of a woodchuck Bears pass the winter in hollow logs, cavities at the base of uprooted trees, or windfalls Field observations indicate that female black bears and their cubs may select the open floor of spruce swamps, protected only by surrounding trees A hibernation bed of a black bear in northern Minnesota, about 4 feet in diameter and lined with a few sticks, was merely a shallow depression in the sphagoum moss and Labrador tea (*Ledum*), with no cover other than that provided by the lower limbs of a black spruce [34] A Minnesota den was found under the arching roots of a dead pine snag and was 18 inches deep by 3 feet wide, a seemingly small abode for a large she bear and three cubs [35]

Bats resort to caves or similarly protected sites (Fig 67) Some pass the winter in relatively unprotected sites, beneath the loose bark of trees, where they are exposed to the vicissitudes of Northern winters [36] Others may pass the winter in heated buildings, occasionally flying about the corridors The big brown bat (*Eptesicus*) has been known to take up its winter residence against steam pipes, where a fairly high temperature was maintained throughout the winter

Time of Hibernation Weather conditions govern the time of entrance into hibernation of many mammals Ground squirrels of the Northwest may become lethargic and disappear below ground by mid June (*Citellus townsendii*), while ripening grain and desiccation of plant life induce the Columbian ground squirrel to aestivate by mid-August

Woodchucks have disappeared by late September or early October, while the lush pastures they have deserted are yet green The hibernation of bats is determined by the disappearance of insects, the bats either migrate or move into winter quarters Chipmunks do not become excessively fat and in the

FIG. 67.—These little brown bats (*Myotis lucifugus lucifugus*) are massed together during hibernation in a Pennsylvania cave. Most bats of eastern United States are widely distributed during the summer. As cold weather approaches, these bats congregate in hundreds or even thousands in the widely separated caves. In such places they are easily caught. Many thousands have been banded and much has been learned of their habits in this manner. (*Photograph by Charles E. Mohr.*)

Northern states are about until mid November Skunks are active until freezing temperatures occur, when the females become inactive, although males may be more or less active throughout the winter if the temperature remains above 15°F [37] Female bears and their cubs "den up" with the advent of sub freezing temperatures, but adult males are less likely to hibernate and do so for a shorter period Jumping mice retreat to their winter quarters with the first hard frosts Raccoons seldom sleep for more than a month at a time, and this sleep usually occurs in late winter

Degree of Hibernation Those mammals which accumulate a store of fat and practice no food storage, exhibit profound torpor Ground squirrels of the *Citellus* group seldom appear above ground during the winter, at least in the northern part of their range Such is likewise true of prairie dogs Jumping mice similarly are profound hibernators, seldom venturing from their den. On the other hand, the eastern chipmunks are up and about through December and January if mild spells prevail Inasmuch as they garner great stores of nuts and seeds throughout the fall, it is probable that they utilize these in their underground burrows during the winter Bats have often been seen flying about during mild periods of winter in the Northern states They have been observed to tolerate temperatures of 14°C yet remain in good health in exposed situations during the winter Bears are less active and their drowsy sleep, if not true hibernation, may be uninterrupted for three months During this period they eat nothing, living on the accumulated store of fat It is said that defecation in the case of the black bear is rendered impossible because the rectum is blocked by a plug composed of pine needles, which is not evacuated until spring Fecal matter of a mother bear who first left her hibernating chamber on March 28 was composed of hair (apparently her own) and numerous old appearing fragments of jack pine The stools were about 1 5 by 6 inches, the outer layer was firm but not hard and the inner section was of the texture of cow dung but more mucilaginous [38]

Length of Hibernation Ground squirrels have been observed to hibernate for 31 weeks in Washington, while a young female remained torpid for 33 weeks [29] Jumping mice hibernate for as much as 26 to 28 weeks, but the period may be considerably shortened by mild weather Chipmunks seldom remain in their dens for longer than 13 weeks, woodchucks sleep for 20 to 24 weeks A mother bear and her three cubs have been noted in the same den for 3½ months, and indications point to an even longer period in others

Young skunks may sleep through 4 months but adults seldom remain denned for longer than a month The raccoon is a light sleeper and may be up and about during mild periods throughout the winter

In the Idaho mountains, at elevations of from 3,000 to 5 000 feet, badgers are always hibernating by January 1 and seldom appear until mid March A trapper naturalist friend informs the writer that on the high mountain tops of the Idaho Rockies snow comes early and badgers may hibernate by mid-October and not appear until mid April If the badger opens its den in the early spring it may often move off several hundred yards and again return to a burrow this time for a 2 or 3-week nap In parts of the Southwest the badger may not hibernate, and in southern Michigan and Iowa the winter sleep seldom occupies more than a week at any one time, the animals usually remaining denned for only a day or two during the severest weather

Bats may hibernate for prolonged periods Vernon Bailey found numbers of pipistrelles (*Pipistrellus subflavus*) in complete torpor in Kentucky caves by late September, although it was still warm outside the caves, numerous insects were flying and there had been no hint of frost Some of these bats remained torpid for 7 months, not venturing forth from their winter quarters until late April

Position in Hibernation Most hibernating ground squirrels chipmunks, and woodchucks assume the same position during the torpor of winter The animal is rolled into a ball the nose

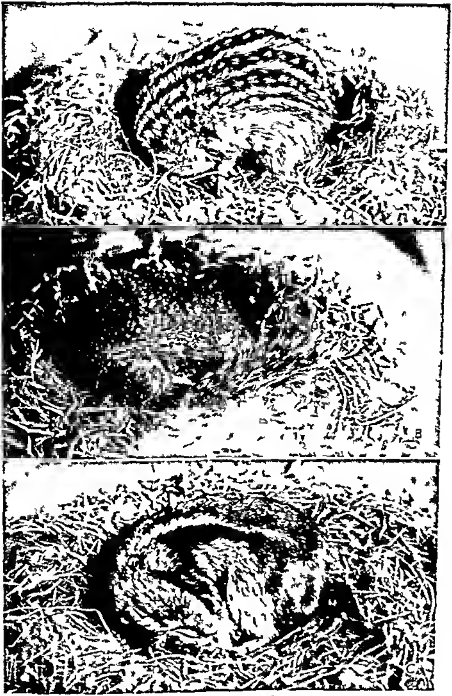


Fig. 68. Hibernating ground squirrels in characteristic positions. In *A*, the thirteen-lined ground squirrel is commencing to arouse from deep torpor. The Franklin ground squirrel (*B*) is in complete hibernation. The golden-mantled ground squirrel (*C*) shows the position of the head and the tightly closed eye during hibernation. (*Photographs by Dr. Otto Wade.*)

touching the pelvis or chest The feet of each side are brought close together, the limbs being rigid, while the tail is laid to one side, over the head, and down the spine The eyes and lips are tightly closed, and animals in deep torpor appear to be frozen into a tight ball (Fig 68) Jumping mice rest in a similar manner, the nose pressed against the inguinal region between the heels and the long tail coiled like a watch spring beneath the animal Bears usually lie on the side, the nose between the fore limbs Because of the cramped quarters of the hibernating chamber, little movement is possible Bats cling to the walls of caves or move far back into the innermost recesses Where abundant, they often hang in large clusters, occasionally clinging to one another, presenting a mass several inches in depth

Awakening from Hibernation The spring emergence appears to be governed largely by temperature, for food is often at a premium and little is eaten even though available Some species, as the woodchuck, may awaken early, mate, and again retire for a short period, but usually the animals remain active when once they have left the hibernating den Ground squirrels emerge from hibernation at rather constant times, although Shaw has demonstrated that cold, snow, and wet weather retarded plant growth and animal activities, resulted in the late development of young, and consequently produced a late season throughout

Woodchucks removed from the hibernating chamber and brought into a warm room become active in less than an hour Increased respiration is evident, the eyes attempt to open, and the fore paws make feeble movements After a bit, normal respiration is established, gasping occurs, and the animal attempts to rise from its side Violent trembling accompanies the animal s efforts to stand up The eyes finally open and the hind limbs again become functional With this return to life the temperature approximates normal The temperature of a ground squirrel emerging from hibernation rose from 38°F to normal 98° in 4 hours

Only in these deep sleepers may we witness such profound changes The light sleepers (bears bats raccoons) maintain a high temperature even when asleep for long periods and can accordingly recover their semi-dormant facilities rather rapidly

Effect of Hibernation While loss in weight during hibernation is considered to be small as contrasted to starvation nevertheless a considerable loss is occasioned Ground squirrels (*Citellus tridecemlineatus*) are reported to lose 41 per cent of their weight during hibernation under natural conditions [40] The Columbian ground squirrel which has a longer period of torpor, loses about 1 gram per day [41] Based on field studies the writer has estimated that woodchucks may lose from one third to nearly half their weight during the 4 or 5 months of hibernation During a 2 to 3 month period in winter female skunks may lose 38 per cent of their weight while the more active males lose about 14 per cent [42] The writer has observed that captive jumping mice (*Napaeozapus*) lose from 30 to 35 per cent of their weight during hibernation Observations on this group of mice suggest that they tend to show a marked loss in weight immediately after hibernation has commenced and that this rapid loss is lessened perceptibly as the winter advances

Aestivation Aestivation is a condition of torpor in which certain mammals pass the hottest season in hot and dry countries contrasted with the similar winter condition known as hibernation This condition seems to have evolved as a means of escape from the recurrent shortage of the food supply brought about by the desiccation of the vegetation

Our Western ground squirrels may disappear into their tunnels by early July or earlier nor reappearing until 8 months later

Animals may be said to aestivate during the fore part of this long inactive period but hibernation truly occurs with the advent of the fall

In the Eastern United States, chipmunks often become scarce during the hot days of August, and some have attributed a summer torpor to account for the scarcity It is more likely that reproductive duties account for the lessened activity, for soon another litter is above ground

BIBLIOGRAPHY

1) Wade, O , 1930 *Jour Mammalogy*, 11 167
2) Hamilton, W J , Jr , 1934 *Ann Carnegie Mus* , 23 155
3) Rasmussen, Andrew T , 1916 *Amer Naturalist*, 50 609–625
4) Johnson, George Edward, 1931 *Quart Rev Biol* , 6 439–461
5) Adler, L., 1926 *Handb der Norm und Path Physiologie*, 17 105–133
6) Dubois, R , 1896 21 *Ann Univ Lyon*, Paris
7) Wade, *op cit* , p. 175
8) Hamilton, *op cit* , p 152
9) Hamilton, W J , Jr , 1937 *Ecology* 18 326–327
10) Simpson, Sutherland, 1912 *Proc Soc Exp Biol Med* , 9 92
11) Mann, F C., 1916 *Amer Jour Physiol* , 41 173–188
12) Shaw, William T , 1925 *Jour Agr Res* , 31 767
13) Hamilton, 1934 *op cit* , p 150
14) Cleghorn, A , 1910 *Pop Sci Monthly*, 77 356–364
15) Johnson, George Edward, 1930 *Biol Bull* , 59 126
16) Dubois R , 1895 *Comp rend Soc Biol* , 47 830–831
17) Rasmussen Andrew T , 1915 *Amer Jour Physiol* , 39 20–30
18) Johnson, 1930 *op cit* , p 118
19) Evans, Charles A , 1938 *Amer Naturalist*, 72 483
20) Horvath, A , 1872 *Zentralblat f med Wissen* , 706–708, 721 724
21) Johnson, George Edward, 1928 *Jour Exp Zool* , 50 26
22) Wade, *op cit* , p 175
23) Rasmussen, *op cit* , p 621
24) Hamilton 1934 *op cit* , p 154
25) Morse, Marius A , 1937 *Jour Mammalogy*, 18 463
26) Johnson, *op cit* , pp 16–18
27) Hamilton, W J , Jr , 1935 *Amer Midl Naturalist*, 16 194
28) Morse, *op cit* , p 463
29) Evans, *op cit* , pp 480–481
30) Johnson, *op cit* , pp 19–20
31) Hamilton, 1935 *op cit* , p 194
32) Hoy, P R , 1875 *Proc Amer Assoc Adv Sci* , 24 148–150
33) Hesse, Richard, W C Allee, and Karl P Schmidt, 1937 Ecological Animal Geography, Chicago, p 409
34) Morse, *op cit* , p 461
35) Aldous, Shaler E , 1937 *Jour Mammalogy*, 18 466
36) Cowan, Ian McTaggart, 1933 *Canad Field Nat* , 47 74–75

CHAPTER X

MIGRATION

MIGRATION is the periodical departure from and return to a region at particular seasons of the year. It is best marked among birds, but occurs among many mammals, amphibians, fish, and invertebrates. The primary cause may usually be attributed to a food shortage, which is well illustrated among the whalebone whales.

The migration of whales is necessitated by the variation in the food supply at different seasons. No whalebone whale could long survive in the immense vasts of the ocean where uniform tropical temperatures prevail throughout the year, for here the minute animal life which provides these great creatures with nutriment is almost wholly lacking. It is only in the far north or in the highest southern latitudes which form a transition from the warm to the polar regions that we find a profusion of this small life and then only at certain seasons. Where fluctuations in the temperature of the sea occur, substances seasonally rise from the depths. These may be likened to the fertilizers we use on our soil to produce crops. Such chemical substances permit a rich development of minute life, which in turn are utilized by aquatic leviathans. As the summer advances and the food supply becomes increasingly abundant northward, the whales follow this source and retreat again as the waters cool.

Heape[1] recognizes three incentives to migration

a Alimental migration, in search of food or water essential for the production of the food required, which is undertaken when these supplies temporarily fail in the home territory and which is invariably followed by a return journey to that home

b Climatic migration, which is undertaken to secure temporarily more suitable climatic conditions and is always followed by a return journey

c Gametic migration, which is entirely distinct from any other kind of movement While alimental and climatic migration are prompted by the needs of the individual, for preservation of individual life, gametic migration is undertaken for the production of the young for their nurture, and therefore, for the preservation of the species, thus while the former is concerned with individual needs, the latter is a racial matter Heape believes this gametic migration to be incited and largely governed by a factor in the reproductive system, the gonadic endocrine gland

Gametic migration has to do with only one half of the migratory movement The fur seal performs a gametic migration when it travels to the rocky inlands of the north but a climatic, or possibly alimental reason, impels it to return to its winter quarters

Whales The arrival and departure of whales from certain seas have long been observed by those engaged in whale fishery The successful pursuit of many cetaceans is dependent on a knowledge of these migratory routes

The California gray whale is a northern species, seldom being found below 20° north latitude These whales frequent the coast of California from early winter to late spring where they resort to the bays and lagoons of the lower coast to bring forth their young As summer approaches the whales work their way northward, remaining close to shore During the summer they congregate in the Arctic Ocean and Okhorsk Sea, returning to their winter haunts with the approach of cool weather Andrews[2] has observed a similar migration in

Asiatic waters, the gray whales there passing southeastern Korea on their southward migration during early winter and returning in the spring, as they pass on to Okhotsk Sea. The humpback whales make a rather general migration from the warmer to the colder latitudes with the change of seasons. Scammon[3] remarks that they go north as the summer approaches and return south when the winter sets in. In the Atlantic, humpbacks are found off Bermuda in late winter, but as spring approaches they leave for Greenland, while at the end of summer they are said to travel south to the West Indies.

In the North Atlantic the whalebone whales migrate northward with the advance of spring, from the Carolinas to Newfoundland. In European waters, according to Hjort[4], the whales winter off Portugal, passing north to the coastal waters of Norway, Spitzbergen, and Iceland. During the antarctic summer there is a migration of whales toward the edge of the ice in the south, the whales keeping pace with the retreat of the ice until they have reached 70° south latitude with the advance of summer. After that there is a movement in the opposite direction, toward Australia, Africa, or South America when autumn and winter set in in the Southern Hemisphere.

Little is positively known regarding the movements of the sperm whale, although Melville[5] in his "Moby Dick" states that the sperm whale definitely migrates vast distances along paths which the whalers call "veins." He even asserts that such travels may extend from the North Pacific to the South Pacific around the Cape of Good Hope. His data are based on the observations of many whalers, who might well be considered authorities on these matters.

Blue whales seldom gather in large schools, but they do spend a good share of their time in migration. These great whales seem to prefer the arctic waters, for they are found in numbers in the early spring about Labrador, Nova Scotia and Newfoundland. At this season they move in a north

easterly direction to the Arctic Ocean where the summer is passed the whales returning in the autumn

With the approach of warm weather porpoises are said to move toward shore they retreat to deeper waters with the onset of winter Little is known of the migratory movements of these pelagic animals

The gray whale seeks the lagoons and bays in lower latitudes for parturition and returns to the colder waters to recuperate and seek the rich plankton life or those species of fish which in turn feed upon such microscopic organisms Hjort[6] has pointed out a marked feature of the life of whalebone whales associated with these migrations In the South food is scarce and when the whales are there it is a period of famine Their capacity to store nourishment in the blubber during times of plenty provides them with a reserve when in subtropical seas Sperm whales can secure an abundance of food at all seasons and are not so dependent on this storehouse of whale oil

Seals No migration of aquatic mammals is more remarkable than the long journeys undertaken by the fur seals These seals (*Callorhinus alascanus*) rove in small groups during the winter the females pups and young males wintering as far south as the latitude of southern California The old bulls winter mainly south of the Aleutians or in the Gulf of Alaska On the approach of the breeding season the old bulls return to the breeding grounds on the Pribilof Islands These tiny, rocky islands 200 miles from the nearest land provide a paradise for the teeming hordes of fur seals and swarms of breeding sea birds The old bulls occupy a position on the rookery ground which they hold until the arrival of the females These females maintain a true course through their 3 000-mile journey buffeting stormy seas and unerringly striking through passes of the Aleutians to the breeding grounds Their sole desire is to reach the islands and be delivered of their pups which are born a few hours or days after their arrival Within a short time the female is again

impregnated, and she repairs to the sea to feed, returning at 2-day intervals to nurse her noisy pup The great bulls watch over their seraglio, never venturing from their station and abstaining from food for 3 full months By early August the cows have all given birth, and the exhausted bulls, gaunt and

FIG 69 —The migration routes of several North American species Whales of several species summer in the arctic seas and spend the winter months off the coast of Lower California. The winter quarters of migratory bats are not well known but they have been taken on ships far at sea and on Bermuda

worn from their long vigil, return to the sea The cows nurse their pups awhile longer and by early November they and their now grown pups start the long trek back to the winter quarters

A good picture of the migration routes of North Atlantic seals has been given by Bartlett During the 3 summer months the hood seals (*Cystophora cristata*) have their home

on the east side of Greenland and the harp seals (*Phoca groenlandica*) on the west side and in Baffin Bay As the ice forms in late September, it signals the start of the southward migration The hoods meet the harps off Cape Farewell (Fig 69) and move southwest to the Labrador coast, near Cape Chidley Swimming close inshore, they reach the Straits of Belle Isle, making this journey in 60 days The seals pass along in strings, the hooded seals taking the outside position, forming a parallel line with the coast The Straits of Belle Isle is an important point in the migration, for here many of the seals turn into the Gulf of St Lawrence However, the main body of seals continues its journey south along the eastern coast of Newfoundland, finally reaching the Grand Banks, while some of the seals may continue to Sable Island After being away from the ice for at least 2½ months, feeding and fattening at sea, the seals start to move north early in February, generally reaching the Straits of Belle Isle by the end of the month The pups are produced at this season and the parents spend several months on the ice after the young are born As the ice retreats northward, the seals pass with it, arriving on the coast of Greenland and in Baffin Bay by early summer

Caribou The migrations of caribou have attracted the attention of man from the earliest times Some years the animals may mass in great numbers and move from the summer to winter quarters, presenting an impressive spectacle (Fig 70) At other times, the herds may be split up into small bands and dribble along, creating the impression of a caribou scarcity in the country Murie[7] has mapped the migration routes of Alaska Yukon caribou but comments on the erratic movements of the herds and the difficulty attendant on a clear picture of the routes Normally the migration commences in the late summer or early fall and is supposedly caused by the search for suitable food Climatic conditions may often affect the availability of food Caribou which summer on the south slopes of the Alaska Range in the Mount McKinley

district, a region of heavy snowfall, move over to the north side on the approach of winter, where the snowfall is much lighter In the Mount McKinley section there is a definite movement from the grassy ranges of summer to the more essentially lichen winter ranges Late in the summer there is a general searching for better food, necessitated by local failure

Fig 70—A herd of migrating caribou The migrations of the barren-ground caribou are eagerly awaited by the Eskimo and Indian for their very existence is dependent on these animals for a source of food and clothing Caribou often swim broad rivers in their travels

or seasonal changes of the vegetation Short wanderings then take on the nature of a migration, probably at first to reach the lichen areas and later augmented by the general unrest of the rutting activities By that time the migration has a definite form and the animals retrace their ancestral routes

In the vicinity of Great Slave Lake caribou are abundant until well into December At that time a large counter clockwise migration occurs, the numbers being augmented

until early March. As the caribou pass the same place at intervals of 2 or 3 weeks on their circuitous course, it is evident that the herds are becoming larger. Finally early in March a wedge shaped migration begins, the animals migrating to the northeast. During the early part of this migration, chiefly bulls are seen, then for a time cows and bulls are fairly evenly represented, while in the last 2 weeks of the migration cows and yearlings make up the vast majority of the caribou observed. Shortly after the caribou have moved on, mosquitoes become exceedingly annoying, especially in the marshes in which the caribou have been feeding. Following terrific gales in July, the mosquitoes disappear. With the elimination of this pest the caribou rapidly return to their winter haunts. It appears that the majority of bull caribou migrate north early in the spring to select good pasturage and there wait until the height of the mosquito season is over in the south. The stragglers remain in the southern part of their range until actually driven north by the mosquitoes. Returning to the south they thus miss the mosquito season farther north.

tions, with cold weather and snow as indirect agents In summer almost all the Yellowstone elk are on the higher mountains and in the forests between altitudes of 8,000 feet and timber line at 9,500 feet From early September through October the elk straggle down in small bands, spending the winter in the snow free valleys, at altitudes usually less than 6,500 feet With the approach of spring the elk return over the same routes they have taken in the fall, but now string out in long single-file herds, often of great numbers, led by the strongest and most resourceful females Skinner believes the longest distance traveled by a Yellowstone elk in normal years is about 80 miles, which is covered in about 50 days The movement is not a steady one, but ebbs and flows with the changes of weather

Mule Deer Like others of its tribe which live in the high Western mountains, the mule deer is migratory The seasonal trips from the bleak stormy mountains are actuated solely by the search for food During October the mule deer descend from their high summer quarters, journeying as much as 100 miles, although many of these movements may not extend beyond a dozen miles If the habitat is more or less uniform over the entire range, no migration occurs Thus Seton[11] says the mule deer of Manitoba are stationary, for the obvious reason that there they find plenty of food and cover and not too much snow

Bison Whether the bison was truly a migratory species was long open to question Hornaday,[12] after a detailed study, concluded that it was a fixed habit of the great buffalo herds to move southward from 200 to 400 miles at the approach of winter This southward movement provided more favorable circumstances than each band would have experienced at its northernmost point Hornaday believed that the movement north began with the return of mild weather in the early spring, thus permitting the buffaloes to escape the heat of their winter range Seton[13] has compiled a mass of records which plainly show the migratory nature of the buffalo

Mountain Sheep In the San Francisco Mountains of Arizona, the bighorns are said to leave the mountains in early winter and cross over Kendrick Peak, 12 miles distant, where they remain until spring, the reason being that there are better food and protection

Bats All our North American bats are either cave-dwelling or tree-dwelling, according to the places in which they spend the day It is well known that the caves, even in Northern states, have a more or less uniform temperature throughout the year Hence animals resorting to these are not affected by climatic changes and can pass the winter much farther north than the tree-dwelling species

The lasiurine bats, or tree dwellers, are known to make extended migrations The hoary bat (*Lasiurus cinerea*) has been found in Bermuda and in the South Atlantic states during the late fall and winter, well removed from its known breeding grounds

The range of the red bat extends from Canada to the tropics and westward throughout the continent, although it is not found throughout this whole region at any one time As it moves south in the autumn, this bat makes long flights across the country or down the coast During October many bats have been found swinging asleep from exposed roots under the overhang of the beach cliffs which fringe the north shore of Long Island, and in all likelihood most such were migrants which had made the journey across Long Island Sound [14]

During the last week of August and the first 2 weeks of September, Miller[15] has reported large numbers of the red bat and hoary bat at Cape Cod, Massachusetts most of which were flying in a southerly direction The writer has observed similar migratory flights in central New York at this season of the year

flew at a height of from 150 to 400 feet above the ground and from their size were believed to be either red bats or the silver haired species

Fragmentary evidence suggests that the sexes of the red bat segregate on their autumnal flights, after the manner of birds Specimens collected at any one time by Mearns[1] proved to be all of one sex

Red bats have flown aboard vessels while on their migratory route, some far out at sea A specimen was collected in August 240 miles east of Cape Cod, Massachusetts That the species makes extended trips over the water in the course of migration is further substantiated by records of their alighting on ships off the coast of Delaware and North Carolina The red, hoary, and silvery bat have all been recorded from Bermuda, and it is not improbable that some at least make their winter quarters on this island

There is some evidence that the cave-dwelling species also migrate, although they probably do not make such extended journeys as the red and hoary bats In observing the bat life of Shawnee Cave in Indiana, Hahn[18] noted that the little brown bats (*Myotis lucifugus*) left the cave about the end of April and there followed a period during which very few were seen flying about in the evening A few weeks later they were again seen in abundance It seems probable that the animals which wintered at this place migrated farther north and that the summer residents had passed the winter elsewhere The fact that these small bats may migrate is further supported by the observations of Howell[19] who saw several small bats in the migration be noted, some of which might have been of this genus

Porcupine Seasonal movements of the yellow haired porcupine (*Erethizon epixanthum*) are definite and pronounced and appear to be governed by climatic factors and food supply[20] Rainfall and the nature of the winter precipitation determine the direction in different regions studied In the humid Northwest the spring movement consists of a slow

and deliberate migration from the cliffs and lava rims to mountain meadows in search of succulent food With the approach of the first cold rains there occurs a more rapid movement back to the shelter of the lava dens, in which during stormy weather the porcupines remain for varying periods At this time an interseasonal migration occurs, the fall and winter feeding being accomplished within a quarter mile of these rim rocks In the more arid Southwest, however, a rapid migration takes place during the fall, extending from the higher elevations down to sheltered areas of the forest, where large numbers congregate for the winter An animal may remain in a single yellow pine for 3 months at this season With the advent of spring and the growth of succulent vegetation, the porcupines again resume their ground feeding and move to the higher elevations as the season advances In the drier region the migration is much more pronounced and extensive than in the humid coastal area Similar migratory movements have been noted in the San Francisco Mountains of Arizona

A remarkable porcupine migration is reported by Taylor [21] Thousands of porcupines were observed in the high Rockies, between Montana and Alberta, during early winter These animals were emerging from every notch far above the timber line, moving westward, so that they were leaving the east slope of the Rockies and going a number of miles through country devoid of vegetation or any kind of food for them They were going into a well timbered country and a warmer territory than obtained on the eastern slope It is not unlikely that this is an annual affair but is seldom observed because of the inhospitable character of the country

and ditches where they breed in banks and subsist on the grains vegetables, and other truck crops After the first hard frosts of autumn a return to the farms and villages may be noted This seasonal migration is reflected in the increased number of inquiries concerning rat destruction which the extension men receive and is probably fostered by alimental needs Some rats remain in the fields during the winter, living in corn shocks or in the sanctuaries afforded by city dumps Even here where underground retreats provide shelter and there is always an abundance of food, rats are more evident in the dwellings close to the dump, especially with the approach of cold weather House mice exhibit a similar seasonal migration

During the drought periods of summer, fields normally inhabited by voles become dry and then mice move into meadows and other damp situations returning to the fields when the vegetation becomes lush from the fall rains

EMIGRATION

Emigration is often confused with migration, the latter term frequently being used for any movement of an animal out of the ordinary Strictly speaking emigration is a desertion of the home territory by a species to which it shows no disposition to return Emigration may be prompted by a lack of food in which the species occupies new territory in its search for a sufficiency it may be for the purpose of finding a more congenial climatic environment or it may be induced by overpopulation occasioned by the extreme prolific nature of the species in several successive seasons

Overpopulation the result of abnormal fertility, has been observed rather frequently among wild animals and often results in mass movements from the normal home site to points which may be far removed It is not abundance of food which stimulates the reproduction rate Heape[27] believes it to be some quality in vegetable food which exerts the most profound influence on both the growth and the reproductive

capacity, as well as the sexual activity, of a greater variety of animals. The condition of the food provides a stimulant or excitant, a vitamin elaborated by young actively growing vegetation which is eaten as food and thus absorbed into the system. A few instances of mass emigration are given that the reader may become acquainted with such phenomena.

Lemming. The classic studies of Collett[23] on the lemming (*Myodes lemmus*) are familiar to many. Colonies of these little mouse-like rodents occupy the birch and willow region on the high Norwegian mountains, close to timber line. They live on succulent grasses and roots and are rather secretive little beasts. Normally they produce one or two litters each summer, generally having four or five in each litter. Periodically the lemmings experience an enormous increase in their reproductive power. The females have three or four litters during the summer. Females from the first litters are bearing young by August. As many as eleven young are now produced in a single litter, contrasted with the customary four or five in normal years. Furthermore, at these times the young show a marked increase in vitality and are enabled to ward off the diseases to which they are normally subject. This combination results in a population so great that the home food supply proves inadequate and great numbers are forced to emigrate.

As overpopulation crowds the teeming hordes to the edge of the plateaus they inhabit, some are forced to occupy the forests. The following season sees a continued increase in their numbers, they are forced farther from their native territory and finally overflow into a land strange and inimical to their needs. The valleys and hill slopes are covered with lemmings; they may be so abundant in the great lemming years that rivers and fiords are filled with their drowned bodies. These hordes always travel to the west, even though barren unsuitable country may be encountered. Many of the lemming hordes eventually reach the ocean strand, whence they strike out to sea and perish.

Associated with this ahnormal fertility in the lemming, we find a similar increase in many animals which live among them Various species of mice, predatory birds, aod carnivores all exhibit a marked increase in the numher of young pro duced during such times It is not beyood the pale of reason to suspect that the predators gain this reproductive stimulus from feeding upon the lemmings, thus acquiring some vita mins which encourage reproduction

Emigration of Squirrels Many remarkahle emigratioos of the gray squirrel (*Sciurus carolinensis*) have been witnessed Immeose numhers congregate io the autumn and move off together, continuing their progress in the same general direction and not turned aside by large streams Gray squirrels are not adept swimmers, but on these journeys they take holdly to water and manage to cross broad rivers, like the Niagara, Ohio, and Hudson Many perish in the attempt, and their bodies sometimes line the hanks of lakes and rivers whicb they have attempted to cross The direction taken by the squirrels may vary The early migrations of gray squirrels have been faithfully recorded hy Kennicott,[24] who witnessed great migrations of squirrels from Wisconsin southwest for 4 weeks at a time These emigrations continued at 5 year intervals for some years So extensive at time were these squirrel journeys that ohservers noted them swimming for 130 miles aloog the Ohio The movements may he local, oot encompassing an area more than 200 square miles, or they may extend over several states

A squirrel emigration of nn mean proportion occurred in Connecticut and New Ynrk during the fall of 1933 More than a thousand squirrels were nbserved swimming the Coo necticut River between Hartford and Essex, a distance of about 40 miles Many of them became exhausted and drowned, while others climbed up on logs nr drift on which they rested as they floated down the river Still nthers came aboard ferry boats or scampered across bridges which span the Hudson River, all moving in a westerly direction [25] Again, during the fall of 1935, a similar and more extensive movement of these

rodents was noted, the emigration extending into western New York. Squirrels were seen where they had been absent for many years, and the bare woods of November disclosed great numbers of large leafy nests made by these animals. Thousands were killed on the highways of western New York, and multitudes were drowned as they attempted to swim the large lakes of the central and western part of the state. With the approach of spring they were gone and 3 years after show no signs of recovery to normal numbers. There is no record of any squirrel other than the gray making these extensive emigrations.

These emigrations arose from one of several causes. Food shortage has been most frequently suggested as the motivating reason for these mass movements. There is much evidence to support this thesis, but there is likewise a lack of proof that food paucity has occasioned all the great movements. Overpopulation has resulted in the inception of these mass treks. During the great squirrel year of 1935, when hordes of these animals moved into New York from New England, the writer had favorable opportunity to observe the squirrels prior to the emigration. The species had been unusually abundant in central New York for several years, and by early July young squirrels of the second brood had made their appearance. It is customary for gray squirrels in Northeastern United States to have two litters of from two to four young annually, one in the early spring and another in the fall. In 1935, and possibly in the preceding year, a third litter was produced, furthermore, the litter size was noticeably increased in all the broods which came under the writer's attention. The fact that greater numbers of young were being produced some distance from the center of the mass movement suggests that this increased productivity was common to all the squirrels that year and accordingly resulted in a density so great that emigration was imperative for the good of the race.

Snowshoe Hare. The startling variations in the snowshoe-hare population have not yet been fully explained, but a reason has been presented for local scarcity following abun

dance During a period of rabbit abundance in northern Minnesota, Cox[26] observed great numbers of these animals moving toward the Northwest This emigration was noted for miles the rabbits crossing a wide lake in their travels Although beset by hordes of owls, their numbers were not greatly reduced and the rabbits continued on their steady flight from their former residence Two weeks later scarcely a rabbit could be found at the point where the emigration commenced Cox suggests that the snowshoe rabbit follows a blind but useful impulse when it leaves its sick companions in overpopulated, overeaten, tick infested, and disease-ridden areas to seek new, clean pastures

Beaver A typical beaver colony consists of an adult male and female, several yearlings, and kits of the year These may total from 1 to 12, the average of 57 colonies studied intensively in Michigan being 5 1 Careful studies by Bradt[27] on Michigan beavers indicate that the two-year-old animals leave or are driven from, the colony shortly before the birth of a new litter of kits The yearlings are permitted to remain These two-year-olds, now sexually mature, move to new quarters and often strike out boldly in a certain direction, although there may be no lakes and streams for miles in that direction Bradt states

their territory by strange animals the new homes must be established in places not already stocked by beavers

That these emigrations at times are extensive there can be little doubt The writer has seen individual beavers or pairs establish a residence on a stream or reservoir in central New York State at least 30 miles removed from the nearest colony

Other Emigratory Mammals Short emigrations of several small Western mammals have been noted by Anthony [28] It is difficult to picture the little chief hare (*Ochotona*) in a habitat other than its home rock slide, but Anthony states that it may undertake a voyage of several miles through unbroken timber in search of new homes The big yellow bellied mar mots have also been observed to make journeys of several miles just prior to the period of hibernation voyaging across sage flats toward some rocky outcrop which might offer shelter The most persistent drifter however, appears to be the bushy tailed wood rat (*Neotoma cinerea occidentalis*), which performs an extensive and regular movement each year in early July, extending over a period of 5 weeks At the time of these movements, the mating season is long past and food is still to be had in abundance It would seem to be chiefly an instinct to seek new habitats before the approach of winter

The Norway rat sometimes performs singular emigrations Eyewitnesses describe these movements as vast armies of rats all moving in one direction Such a movement occurred in western Illinois in 1903 For several years before this emigra tion, no abnormal numbers were seen, and their coming was remarkably sudden [29] These animals remained on the farms and in the villages of the surrounding country and during the winter and summer of 1904 were a veritable plague In 1877 a similar emigration occurred in parts of Missouri These extensive movements are probably caused by unusual repro duction or food scarcity It is said that in England rats swarm to the coast during the season of the herring fishery, feeding on the offal and waste discarded by the fishermen, and at the close of this fishery they return to the farms and villages

NOMADISM

Many animals live a wandering life necessitated by a search for food While not often recognized, a marked characteristic of nomadic life is the regularity of the movements As we shall see below, wolves and seals at times other than the breeding season move with astounding regularity over their hunting range Heape[30] has borne out this view by citing the movements of various nomadic tribes of men. In the case of both the Arabs of the Arabian desert and the Somalis of Africa, who are true nomads, the movements are remarkably regular year after year. Whales cover vast areas of the sea, following with regularity the appearance of marine organisms upon which they feed

Wolves Except during the season when wolves are occupied with family duties, they organize into packs, and, at least in the North, lead a roving life, which may cover several hundred square miles. During the winter hunting units or packs may number from 5 to 30, although the smaller groups are by far the most common These small packs usually represent a pair of old wolves and their surviving pups or, in the case of larger packs, several families which have banded together Such packs may travel 30 or 40 miles in a day. According to Olson[31] they ordinarily have a beat which they cover every 2 or 3 weeks The course a pack travels is in the shape of a great uneven circle, the diameter of which is often 30 to 50 miles In years of abundant game, the circle is small, but if game is scarce, Olson concludes, it may be several hundred miles in length Some of these routes have been used for generations, the wolves returning to the identical pass at intervals of 3 weeks The fact that hunting is always easier in a region which has been undisturbed for several weeks may account at least partly for the great range of some of these hunting trails

Seals During the frozen Northern winter, the Arctic Sea is covered with ice of which the thickness may reach

10 feet. No seals are found on this ice, but in the polar current beneath it they lead a nomadic life, feeding on the fish which in turn are attracted by the plankton The seals break holes through the ice early in the winter, gnawing from below as the ice thickens, so that a conical passage is prepared, wide at the bottom but scarcely 3 inches across at the ice surface Here the seals repair at regular intervals, and the hunter, waiting at these blowholes, spears the seal at its approach and hauls out the body through the hole he has enlarged Stefánsson[32] noted the regularity with which the seals patrolled these holes, and he and his Eskimo companions lived on seal meat only for many months, eventually returning to civilization long after he had been given up for dead Stefánsson had abiding faith in the regularity with which the seals visited their holes and staked his life on their nomadic habits He indeed had lived a similar life during all this period, wandering over the frozen Arctic Sea far from land

19) Howell, *op cit*, p 38
20) Gabrielson, Ira N, and E E Horn, 1930 *U S Dept Agr Leaflet* 60, 3
21) Taylor, Walter P, 1935 *Univ Ariz Biol Sci Bull* 3, 155–156
22) Heape, *op cit*, p 96
23) Collett, R, 1895 *Videnskabs-Selskabs Forhandlinger*, No 3
24) Kennicott, Robert, 1857 *Ex Doc* 32, *35th Congress, House of Representatives*, 64
25) Anthony, H E, 1934 *Literary Digest*, p 30
26) Cox, W T, 1936 *Jour Mammalogy*, 17 216–221
27) Bradt, Glenn W, 1938 *Jour Mammalogy*, 19 160–161
28) Anthony, H E, 1923 *Jour Mammalogy*, 4 60–61
29) Lantz, David 1909 *U S Dept Agr Bull*, 33 17
30) Heape, *op cit*, p 329
31) Olson, Sigurd, 1938 *Ecology*, 19 168–170
32) Stefánsson, V, 1921 "The Friendly Arctic," New York

CHAPTER XI

MAMMAL POPULATIONS

Those who have bad opportunity to study animals in their environment over a period of years cannot help having noticed that populations of any species are seldom constant The abundance of the common tent caterpillar during some years and its almost total absence a few springs later is a matter of common observation Hunters who have long pursued their avocation realize that game animals have periods of abundance and scarcity, the periodicity of which is quite regular The Northern trapper, dependent for a livelihood on his catch of fox and lynx, realizes full well that his returns will vary from one year to the next, even though be may use the same number of traps each season Some autumn the woods will swarm with shrews, the next spring the shrews are unbelievably scarce In brief, few mammals appear to have a stable population equilibrium Each species, but more particularly Northern forms, appear to pass through this natural process of ehb and flow These fluctuations are commonly known as cycles A complete cycle among mammals may run through a period of 3 years or it may take several decades

Unfortunately, few students of animal life appreciate this principle of fluctuating populations Most naturalists still hold to the theory that living organisms are in a stable equilibrium the balance of narure It is widely assumed that, if

environmental conditions are at all favorable for any species, the species will commence to increase in numbers, with the obvious result that there is more food for its predators, parasites, and disease producing organisms This gain in the predator population tends to reduce the host population and a food shortage for the predators results With fewer enemies, the species again commences to multiply This process is often likened to a pendulum, the vertical line representing the normal condition Uvarov[1] has assembled a mass of data which suggests that the current notion that living organisms are in a stable equilibrium is nothing more than fiction He writes

> This theory of a stable equilibrium in nature is, however, in direct contradiction of the facts While it is true that an increase in numbers of a species is usually only temporary, and that a decrease will sooner or later, follow, there are no proofs that the fluctuations in the two directions are of an approximately equal magnitude, as in the case of a pendulum Nor is the so-called normal number a constant We know that some species become gradually more numerous or expand their area of distribution while others die out We know that whole biocoenoses undergo a continuous change an ecological succession, which represents only a short phase of the much longer process of geological succession To speak of a stable equilibrium in nature and to compare the fluctuations in numbers of organisms with the regular movements always returning to a non-existent normal condition is contrary to common sense and amounts to a denial of organic evolution We may compare the course of the existence of a species to a pendulum in motion but we must introduce two corrections The first is that the fluctuations of such a pendulum are entirely irregular, both as regards their velocity and their magnitude in either direction The other correction is that the pendulum is not suspended from a fixed point, but that the point itself both fluctuates irregularly and moves with an unequal velocity along an unknown and apparently irregular course These corrections which are absolutely necessary make the theory of a stable equilibrium in nature and its comparison to a pendulum appear wholly artificial

This natural unbalance of populations is reflected in the relations of arctic mice with other Northern animals Of great interest and significance are the observations of Cabot[2] On his first visit to northern Labrador and the interior of

Ungava in 1903 he did not find mice noticeably abundant Caribou had been abundant throughout the winter and during early summer they passed north in large numbers, close to the coast A few falcons and rough legged hawks were about Few ptarmigan were present, although foxes were rather plentiful The following year mice were distinctly abundant Hawks became more numerous and the numerous foxes were shy, gorging on mice and difficult to entice into baited traps Wolverines that were killed proved to be full of mice The caribou were scarce In 1905 the mice were extraordinarily abundant, often two being seen at one time in daylight Low twigs and all small growth were riddled by them The moss and ground cover was torn and tattered Birds of prey had noticeably increased Even the larger trout were feasting on mice Ptarmigan were very plentiful, and the wolves, abundant now were silent still Bears were gorging themselves on mice A remarkable change came over the country with the disappearance of mice in the spring of 1906 Raptores disappeared, and the trout still numerous now fed on flies Bear turned to berries for sustenance Ptarmigan grew scarce In all probability these birds had been let alone by the predators who sought easy living on the mouse millions Thus the birds were able to increase to unusual numbers The hunting cry of the wolves was now heard as they moved on the caribou herds The abundance of mice affected all the game Great numbers of mice tended to build up the ptarmigan population which are of much importance to the forest Indians The shore people were likewise affected All their land game came or went was plenty or wanting shy or easily taken according to the supply of mice One can readily imagine the significance

experiences, so startling, that the vividness of their abundance can never leave me A certain brushy flat adjoining the White Mud River, southwest of Edmonton, yielded the initial surprise It was grown to scrub willow, the common trembling aspen, and to some extent with rank under vegetation The place was infested I do not hesitate to say that over that tract of perhaps thirty acres hundreds of hares were found October had come, without snow The rabbits had already, wholly or in part, donned their snow white livery of winter, and were consequently very conspicuous against the mellow brown of the autumn woods At every turn during my ramble they popped up here and there and scurried for fresh cover Not only in singles, which was astonishing enough but often twos and even threes started up in wild alarm The newness of such an experience does not soon wear away One receives a peculiar thrill at each additional incident Scarcely has one received the impression of the previous fleeing object than perhaps another startlingly rockets out from nearby underfoot, stirring up several more in the haste of evacuation After the first wild impulse of flight, which is generally deferred until the last moment, the rabbit bounds leisurely away, sometimes out of sight but as often calling a halt within a few yards Over the country to which these remarks broadly refer, namely, the northern and western parts of Alberta, the rabbits often become a plague The toiling trapper, depending on the effectiveness of each of his traps they drive to a form of desperation Night after night along the whole long line the cubby or bait pens are torn down or in some way molested

Eventually evidence of the inevitable decline arrives Empire among the rabbits as elsewhere has its rise and fall, and then is swept away A strange peril stalks through the woods the year of death arrives An odd rabbit drops off here and there, then twos and threes, then whole companies die until the appalling destruction reduces the woods to desolation There is something almost spectacular in its compass, in its silent and sinister progress I have walked the woods where formerly hundreds of playful rabbits dwelt where signs were evident on every hand yet the woods were empty A peculiar sense of lonliness comes over one under such circumstances One year (1917) in the district of Sudbury, northern Ontario, the signs of rabbits were everywhere but not a single rabbit could I start It seemed incredible Local inquiries disclosed that a little over a year before the *Lepus* population was beyond count Now as if by magic they were gone Needless to say, however a few individuals survive the epidemic These now, because of their paucity are seldom observed The following year at Ridout same locality, I observed a noticeable increase Not that they were plentiful or even common by any means but there were frequent trails in the early snow and I started occasional animals In these few existed the prophecy of another dominion

CYCLES

This ebb and flow of animal populations which has just been referred to is called a cycle Cyclic animals are those which exhibit a more or less regular periodicity in their numbers, now abundant, then scarce These cyclic periods vary in length with the species, the smaller forms having a shorter cycle than large species Thus the lemmings and field mice have a 3- to 5-year cycle, squirrels 5—or 6-year cycles, and the length of the snowshoe hare cycle is estimated at 10 years Species dependent on any cyclic animal for a major share of their food often have their own cycles approximating that of their prey These cycles may be well defined and regular, occurring at such definite intervals that it is quite possible to predict when a given species will be present in some numbers, only tolerably common, or scarce Cycles are much more pronounced in the North, more especially in boreal species, but there is evidence that such cycles do occur in the tropics

Jack rabbit populations in Minnesota may change from a few to more than 69 hares per square mile, but the most usual number falls between 10 and 20 [4] These fluctuations do not affect the whole country simultaneously, for at the same season the rabbits may fairly swarm in one valley and be scarce in another Studies of the jack rabbits of southern Arizona have not revealed strongly marked fluctuations [5] The intensity of the cycle is not always the same, there being considerable variation in the total numbers on any given area from one peak year to the next In the most favored habitats, the cycle is likely to be more pronounced, for here the population, even when low, is well represented

Characteristics of a Population Cycle Few biologists have had opportunity to follow closely the events which transpire during a complete cycle The biology of the 4-year field mouse cycle has been studied closely by the writer [6] The course of events appears to be similar in other small cyclic

mammals Following a drastic decline in numbers, sometimes as much as 80 per cent, the species begins to recover its numbers Because there are fewer mature individuals, there is less opportunity for mating among these promiscuous voles, and as a result there are fewer litters in a season Moreover, for unexplainable reasons, the number of young per litter is rather small and the breeding season seldom lasts longer than 7 months If winter conditions are favorable, the breeding stock during the following spring is measurably larger than

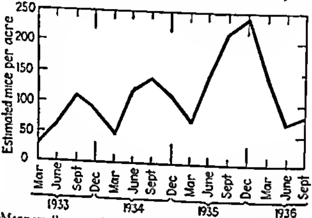


FIG 71 —Many small mammals are incredibly abundant one year and all but absent the following year Field mice may number several hundred per acre during the peak of their cycle and drop off to a dozen or two per acre in a few months The population soon recovers The variation in the mouse population above occurred in a 20-acre orchard in central New York

that of the previous spring Reproduction may commence a week or 10 days earlier, larger litters are produced, and, because of the increased number of mature mice, a greater likelihood of mating is afforded Thus the litters succeed one another more rapidly The breeding season is prolonged, possibly extending into early November The same events follow the next year, except that every phase is accelerated Finally, the fourth year of the cycle finds great numbers of mice, all fecund and ready to breed The season of reproduction may carry through the winter, so that young are produced in the coldest months, although the litter size at this season

is reduced (Fig 71) Collett[7] states that the young of lemmings born in these prolific years are possessed of greater powers of attaining maturity and resisting disease than are those born during a normal year Finally a pandemic occurs, which stalks through the ranks, taking a large share of the population in a very short time, often a matter of but a few weeks The greater the density of the population, the more drastic the decline This, in brief, is the course of events as observed in a wild mouse (*Microtus*) population under natural conditions

The course of reproduction in the snowshoe hare cycle follows somewhat along the same order, insofar as increased reproduction during the waxing of the cycle is concerned MacLulich,[8] after much field work, believes that in the first year after the lowest point reached by the population, females produce only two young per litter, three young the succeeding year, four young for the year of greatest increase, then three young for one year, and during the time of decrease only two young The females produce two litters per season, except during years of decrease, when only one litter is produced before the adults die of epidemic disease The writer has observed an increased reproductive rate in the deer mouse (*Peromyscus leucopus*), the short tailed shrew (*Blarina*), the chipmunk (*Tamias striatus*), and the red squirrel (*Tamias ciurus hudsonicus*) during years when populations of these animals were increasing In the seasons of scarcity, the embryo counts have always been relatively small On the other hand, Howell,[9] from extensive study in Western United States, concludes that during years of great abundance of a given species reproduction appears to be curtailed When jumping mice were swarming in the Cascade Mountains of Washington and were caught in great numbers, approximately 5 per cent of them were immature animals

Cause of Cyclic Population Many theories have been advanced to account for the tremendous variation in population levels that mammals exhibit from one year to the next

Abundance of food, absence of predatory enemies and parasites, presence or absence of sunspots, and other factors have all received attention The basic underlying reasons for these variable populations have not yet been pointed out, but certain agents appear to be contributory and are discussed briefly here

Sunspot Theory While the exact nature of sunspots is not fully understood, it is known that these spots appear from time to time, varying in their figure and dimensions They last from a few days to several months, occuring with periodic frequency, the length of the cycle being 11 13 years (the

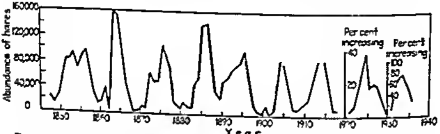
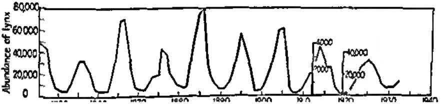


Fig 72 —The abundance of varying hares in winter plotted over end of year in which the winter began, i.e. after the season of its biological production Basis of curve from Hudson's Bay Co fur returns and miscellaneous sources (*After MacLulich*)

sunspot theory or cycle) The appearance of these spots is accompanied by diminished light reaching the earth, sometimes by heat loss, and often by magnetic storms on the earth Many scientists have attributed the variation in animal populations to the influence of sunspots on earth climate There may be some coincidence existing between the periods of sunspot maxima and minima and the periods of plant growth Nevertheless, tree ring records indicate that the last period of 19 years of drought and poor tree growth represents a major fluctuation in a broad climatic cycle which eventually will be followed by a wet period of better than average growth *No rhythmic cycle has been found* which would permit a prediction as to when the reversal in trend will occur [10] As Anthony [11] has observed the coincidence between

the sunspot maxima and minima and the periods of plant growth and animal population cycles is troublesome because it hints of too much to be overlooked and yet the theories which attempt to show causal relations are by no means conclusive The Matamek Conference, held in 1931 to discuss rhythm in animal populations, considered the sunspot theory in accounting for a great variety of cyclic phenomena One of the strongest impressions of the whole conference was that all sorts of cyclic populations must be controlled, though not necessarily caused, by some outside forces which dominate all forms of life If these are solar forces, they manifest themselves as sunspots prominences, faculae, the solar



between the rabbit cycles and the 11 2-year sunspot cycle The lack of complete simultaneity in these fluctuations over the entire country was inferred to be dne to the sunspot variation's causing a cyclic shifting of the isoclimatic lines, with the result that rainfall increased at some places and decreased at others Others have correlated the sunspot minima,[14 15] with maximum numbers of grouse and grasshoppers In a survey of the grouse cycles of Britain and America, Leopold[16] found no significant synchronism, the periods being quite different Unless fluctuations operate in quite a different manner in America and Britain, Leopold's observations would seem to refute the theory that cycles are basically due to sunspots or other solar phenomena. After a critical analysis of fur returns, MacLulich[17] concludes there can be no relationship between sunspots and lynx abundance, inasmuch as the average lengths of the cycles were 9 7 years for the lynx and 11 1 years for the sunspots These facts in themselves mean that the two cycles cannot be correlated but are independent. The fact that lynx abundance is not correlated with sunspot numbers is strong evidence, amounting to proof, that rabbit numbers are not related to sunspots The duration of the rabbit cycle is the same as that of the lynx (Fig. 72)

One can scarcely doubt that variation in solar energy has its effects upon our climate, and this in turn reacts on plant life Inasmuch as animals are directly dependent on plants, their relation to such phenomena is not difficult to envisage Nevertheless, evidence accumulated in recent years tends to discount many of the studies in which cyclic species have appeared to fluctuate in relation to sunspot cycles. Many species pass through cycles the length of which may in no way be correlated with solar activity.

Cycles and Food. It is conceivable that a population of any species, unhampered by the prevalence of enemies or disease, might increase to a point where their numbers will find an insufficiency of food and will thus starve Indirectly, as a result of low food rations and the resultant emaciated condi-

tion, weakened animals would stand little chance of surviving severe winter storms. At the height of snowshoe-hare abundance in parts of Ontario, the forest was not producing bark at the rate it was being consumed, but considered over the 10-year cycle sufficient bark was certainly produced to stand the one year's heavy cropping.[18] There is evidence that the Canadian lynx, dependent on the snowshoe hare during the

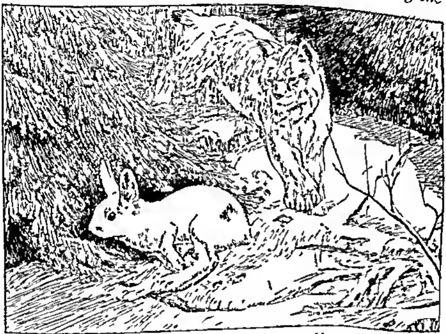


Fig. 74.—The Canada lynx depends upon the snowshoe rabbit or varying hare for its sustenance. Both are cyclic species. When the hares become scarce, the lynx population declines.

winter months, starves miserably as the rabbit hordes disappear (Fig. 73). Seton[19] comments on the rapid decrease of the lynx population following the rabbit epidemic of 1906 to 1907. During a 7-month journey along the Athabaska River he met with a dozen lynxes that were dying of starvation—merely walking skeletons—and in the silent woods found a dozen shriveled corpses. There were thousands of starving lynxes roaming about the country, combing the

woods for any last vestige of animal food Every item of evidence, states Setoo, helped to emphasize the dire story of the plague and of the famine that came after

During periods of mouse increase in the arctic, the food supply may become locally imperiled, but epidemic usually stalks the mice before they are threatened with starvation The minor mouse plagues of Northeastern United States never make any noticeable impression on the food supply Few animals ever increase up to the limits of the means of subsistence, as Malthus believed McAtee[10] writes

> Populations usually are checked far short of a subsistence limitation Automatic restriction by lowering of birth rate in response to density and by a great variety of self limiting phenomena, together with sweeping indiscriminate destruction of immature forms, involving little or no actual competition either among themselves or with adults seem to be the principal factors involved in maintaining the stability of populations

Causes of Decline Much conjecture and not a little study have been centered on the causes which bring about the sudden and devastating decline of cyclic mammals Some hold that a lack of food has resulted in widespread starvation This may be an important factor in reducing the lynx population for these cats are dependent chiefly upon the snowshoe hare for their main sustenance, and with periodic decrease of the hare famine would result Predation probably has little significance in reducing materially the numbers of a species when it reaches its period of greatest abundance Slow breeding predatory animals cannot keep pace, proportionally, with the fast breeding herbivores, which in a single favorable season may easily increase their numbers tenfold A decline in the birth rate cannot account for such sudden decrease, for we have seen previously that some mammals, notably field mice, continue to have large litters up to the time of the drop-off

The most logical explanation of the periodic die-off of cyclic animals is, then the development of epidemic disease There

is much evidence to favor this idea Not a few of those species which periodically increase to tremendous proportions have been studied during the decline, and a number have been found to be afflicted with disease, often of an epizootic nature Green[21] and his associates, after long study, attribute the die off of Minnesota snowshoe hares to shock disease Hares suffering from this disease appear perfectly normal until they are suddenly stricken with convulsions and die in seizures or abruptly sink into a fatal coma These seizures usually are hypoglycemic in character, death being due to an abnormally low blood sugar The liver degenerates because of its failure to store glycogen Animals under favorable conditions of captivity would suddenly spring into the air in convulsions or sink to the ground in coma In either case, death usually followed from a few minutes to an hour after the onset of symptoms This type of sudden death of hares was observed in the woods under entirely natural conditions Such infectious diseases as tularemia were found to play but a minor role in the mortality of the hares Moreover, the general picture of the decline, continuing until populations are very low, is not one typical of the course of an epizootic disease MacLulich[22] records a number of diseases common to the rabbits during their decline and concludes that the epidemic is not always

MASS OUTBREAKS

The spectacular periodic irruptions of small mammals have long excited the wonder of naturalists, so that an extended literature has resulted. The irruptions of the Norwegian lemmings have been faithfully recorded by Collett,[26] of Russian voles by Plater Plochotzkij[27] and of field mice by Piper.[28] The events leading up to these mass outbreaks have been recorded many times. A description of the outbreak in the Humboldt Valley of Nevada will suffice for all. Always present in the Humboldt Valley, field mice (*Microtus montanus*) attract little attention when occurring in small numbers. Usually they are not uniformly abundant in the district, in fact in many of the fields they may not be present at all. They live in scattered colonies, in swampy places, or along the borders of sloughs and irrigation ditches. When the mice are normal in number a little damage may be noticeable about the borders of fields or along ditches. Ordinarily they are very prolific, each pair producing four to six litters of about six young each during the long breeding season. Occasionally conditions favor excessive multiplication, and under such circumstances damage soon becomes evident and in a single season may increase locally to the serious injury of fields. The mice extend from such centers during the next breeding season and increase not only by reproduction but by joining with other colonies, and a vast army of mice is formed. Because of overcrowding and the limitation of food, such armies invade adjoining districts and this progress becomes more rapid with the disappearance of green food in the fall. Through the combination of several such armies, entire districts are overrun. In the Humboldt Valley, mice first attracted the attention of ranchmen early in the spring of 1906 and the numbers increased alarmingly the following summer. The height of abundance was reached in November of that year, when it was estimated that on many large ranches there were from

8,000 to 12,000 mice to each acre. This density is equivalent to a hundred mice in the average-sized room of a small house.

An outbreak of house mice occurred in Kern County, California, during January, 1927. At the source of this irruption, in the dry bed of Buena Vista Lake, Hall[29] found as many as 17 mice per square yard over an area of many acres in extent. He computed there were 82,280 mice per acre in the most densely occupied areas. So abundant were they that automobile traffic was made perilous by the slippery nature of the highway, caused by the crushed bodies of countless scores of mice. Suggested causes of this mass increase were favorable meteorological conditions, abundant food and shelter, and removal of the principal natural enemies of small rodents that normally hold their numbers in check. The factor determining the time of the spectacular emigration of the mice was, probably, the destruction of their food and shelter.

Such outbreaks as have been recorded, it should be noted, usually are more or less local in nature and frequently occur in arid regions which have been transformed into arable conditions by irrigation. No mouse irruptions on this scale have been noted in the East, where the species may be widely scattered and occupy a number of ecological associations. While field mice do become excessively abundant at periodic intervals in Northeastern United States, their numbers seldom surpass an optimum of 300 per acre, and then only under unusually good conditions. This increase covers a much greater area, however, there being evidence that during the winter of 1935–1936 field mice were unusually abundant from Indiana to the Atlantic Coast and south into the Shenandoah Valley of Virginia.

5) Vorhies, Charles T, and Walter P Taylor, 1933 *Univ Ariz Agr Exp Sta Tech Bull*, 49 555
6) Hamilton, W J, Jr, 1937 *Jour Agr Res*, 54 779-790
7) Collett, R, 1895 *Videnskabs Selskabs Forhandlinger*, No 3
8) MacLulich, D A, 1937 *Univ Toronto Biol Ser* 43 91
9) Howell, A Brazier, 1923 *Jour Mammalogy*, 4 143-155
10) Keen, F P, 1937 *Monthly Weather Rev*, 65 188
11) Anthony, H E, 1934 *Literary Digest*, 30-31
12) Huntington, Ellsworth, 1931 *Science*, 232
13) Elton, Charles, 1924 *Brit Jour Exp Biol*, 119-163
14) DeLury, Ralph E, 1930 *Canad Field Nat*, 120
15) Criddle, Stuart, 1932 *Canad Field Nat*, 195-199
16) Leopold, Aldo, 1931 *Canad Field Nat*, 162 167
17) MacLulich, *op cit*, p 113
18) MacLulich, *op cit*, p 100
19) Seton, Ernest Thompson, 1929 Lives of Game Animals, New York, 184
20) McAtee, W L., 1936 *Scientific Monthly*, 456
21) Green, Robert G, and Carl L. Larson, 1938 *Science*, 298-299
22) MacLulich, *op cit*, pp 91-97
23) Findlay, G M, and A D Middleton, 1934 *Jour Animal Ecology*, 150-160
24) Hamilton, *op cit*, pp 781-787
25) Wayson, N L, 1927 *U S Pub Health Repts*, 1489-1493
26) Collett, R, 1911-1912 Norges Pattedyr, Christiania
27) Plater Plochotzkij, K A, 1930 *Sauch Rast of Vred* (Plant Prot), 6 [illegible]
28) Piper, S E, *U S Dept Agr Farmers' Bull* 352 5-22
29) Hall, E Raymond, 1927 *Univ Calif Publ Zool*, 30 189-203

CHAPTER XII

BEHAVIOR

The behavior of wild mammals in their natural habitat has been little studied When we consider the secretive habits and nocturnal activity of many species and the inherent wariness of the larger forms, this lack of knowledge is hardly surprising A study of the temperament, senses, gregarious or solitary dispositions, and similar phases of any mammal s life history can hardly be pursued under field conditions There are notable exceptions, such as the fine observations which have been made by various observers on the fur seal, new-world monkeys, and other social species, but these studies have proved the exception Moreover, observations on the behavior of housed animals are seldom significant, restraints which captivity imposes seldom permit the animal to carry on in a normal fashion

shell like skin serve to minimize death through predation All who have observed a porcupine have marveled at its dense coat of modified hair spines This eqnipment holds little fears for many predatory beasts, for bobcats, foxes, coyotes, and mountain lions are known to enjoy a meal of porcupine meat upon occasion

Malodorous Secretions Many mammals, particularly those of the weasel tribe, are provided with large anal glands, the ontents of which may be discharged at the will of the owner The mink, weasel, and marten all possess these glands and are not hesitant to use them The most notable owner of such weapons is the skunk, whose mephitic odor is familiar to almost every rural dweller The effluvium is housed in two large glands, about the size of a grape, situated on either side of the vent and lying just below the skin These glands discharge their contents through short ducts leading to tiny white-capped nipples lying just within the anus When the animal is greatly alarmed or attacked, the tail is raised over the back, and the glands discharge their contents, often with some direction on the part of the skunk The yellowish fluid is emitted in two tiny streams and is often thrown a dozen feet The odor is so pronounced that it may be carried on the wind a half mile At other times little smell is apparent The animal is said to be incapable of discharging its guns if held by the tail, but the writer knows through sad experience, that such is not always true Skunks and their kin discharge this effluvium only as a last desperate measure, the skunk preferring to give repeated warnings by raising the tail in threatening manner, as if to intimidate the enemy

Trapped ground squirrels in Alaska when approached, have been noted to direct their rear toward the observer and at the same time, protrude three anal papillae [1] The squirrel assumes a half-crouched position raises the fur so that it stands on end, exposes the teeth by drawing back the lips, and produces various notes of a threatening tone—altogether suggesting a state of extreme rage which might well cause an

opponent to regard the squirrel as a formidable adversary! Trapped woodchucks when approached evert the anal papillae aod give off a characteristic musky odor, undoubtedly serving as a warning signal to their enemy Elsewhere it has been suggested that these organs are used as a communicating agent, the animals apparently apprising one another of the presence or absence of enemies

Autotomy of Tail Antotomy of an appendage is supposedly restricted to lizards and salamanders The spiny rats (*Echimys* and *Proechimys*) appear to exhibit this trait Maoy specimens taken by collectors are without a tail, and this led naturalists[2] who were studying Trinidad mammals to observe the posterior portion of the vertebral column of these small rats They found that amputation occurs at the second vertebra behind the posterior border of the pelvis or just beyond the fifth caudal The first four caudals are normal in size and proportions and appear to be in every way natural, but the fifth caudal is unnatural, the posterior third or half having been apparently lost by absorption When the animals with the tail intact are skinned, it was noticed that this member often breaks off at the fifth caudal vertebra About 25 per ceot of the rats (*Proechimys*) trapped in Panama were without tails Has the animal the power or ability, when grasped by the tail, to leave this member in the claws or teeth of its enemy and so escape with its life? Parallel examples are to be found only among the amphibia, *i e*, *Hemidactylum*, or various lizards, which leave the wriggling member behind and make good their escape A parallel to this condition may be found among the pocket mice (*Perognathus*), whose tails at almost any point may readily be separated by a whirling motion of the body or by a sudden leap of the animals when they are held by the tail and placed on the ground The tail tip normally is provided with a pencil of hairs, when part of this member is lost the stump acquires such a pencil by additional lengthening of the sparse hairs which usually cover the entire appendage Whether this may be considered a protective

adaptation we cannot say, but it does seem as if the loss of the tail, so readily accomplished when grasped by tooth or claw of a predator, could aid its owner at critical times There does appear to exist some association between the fragile tail and the peculiar instinctive responses of the mouse when grasped by this member [2]

Fig 75 —The opossum feigns death The animal will actually close the eyes open the mouth and extrude the tongue This protective behavior of "playing possum" is so realistic that the animal is often considered dead by the uninitiated

Death Feigning A number of lesser animals, some reptiles and a few mammals feign death when alarmed Among the latter, none carries this to such extremes as the opossum This slow witted beast deceives an enemy by dropping limply on its side, thus appearing quite lifeless (Fig 75) The tongue lolls from the partly opened mouth, the eyes are tightly shut and the animal falls into a limp heap if taken up and dropped from a short height This unique deceit has misled many of its captors, unfamiliar with the opossum, to believe that they have frightened the animal into a lifeless state The opossum is capable of maintaining this pose for many minutes

Other Defense Methods In the Panamanian jungles the red spider monkeys, when pursued or frightened by a terrestrial adversary, break off sizable branches and cast them, with some effort at directed aim, toward the enemy Occasionally a limb or small branch is broken off and held for a moment or two until the adversary draws closer, when the object is thrown Related to this behavior of dropping objects toward the observer or enemy is the common activity of releasing fecal matter and urine with reference to him According to Carpenter, it appears quite clear that these behavior patterns can be classed as instrumental acts carried out with reference to particular defensive objectives

Howling monkeys, when alarmed or much excited by an intruder or strange object below, will defecate on the object and quickly move on While observing these monkeys from a blind, Carpenter[4] has observed the animals to release fecal matter on the blind as they passed over it The animals would stop, complete the act, and then hurriedly continue This procedure of dropping excrement, branches or other objects on a disturbing element appears to be a kind of primitive instrumental act

The kangaroo rat (*Dipodomys deserti*) has evolved a unique method for determining whether a mound or some such object on the sandy desert floor conceals danger[5] As it approaches such an object, the rat turns, and with force and precision kicks some sand on the pile with its strong hind feet, then whirls about immediately to watch the effect The action may be repeated several times until the rat is assured that no danger threatens It seems highly probable that an animal struck by the sand would betray its presence by some movement however slight This habit would undoubtedly have survival value against the rat s archenemy, the sidewinder rattlesnake which also lives in sandy places and is known to feed on the rat

Desert pack rats have adopted an interesting military development in fortifying their nests and trails similar to the

use of barbed wire in modern warfare Hill states that the rats pile upon their homes the cholla cactus, whose needles are most painful and point in every direction The pack rat can walk on these needles with impunity, frequently climbing the cholla for its fruit Apparently this is possible because the body weight of the rat is light in proportion to its foot surface Moreover, these rats often pave their runways with the needle-sharp spine clusters They are thus free from the attacks of predatory mammals which would hardly dare risk the formidable spines [6]

HOMING BEHAVIOR AND TERRITORY

The reader is undoubtedly familiar with the homing "instinct" displayed by the house cat when liberated miles from its residence This behavior is apparently well developed in most of our native mammals, for all species in which the trait has been studied exhibit a marked sense of direction In order to determine the homing behavior in deer mice, the Muries[7] marked a large number of these mice in the forests of Wyoming The mice were then liberated at varying distances from the point of capture One immature deer mouse, released 2 miles from the point of capture, returned in 2 days or less to its homesite Inasmuch as the home range of these mice is rather restricted, it appears highly improbable that their return could be attributed to familiarity with the terrain, nor is the probability of their returning by chance a likely one It thus seems apparent that the species has some means of orientation plus a desire to return to its original homesite The writer has similarly marked Eastern deer mice and released them at distances varying from ¼ to 1½ miles from their home quarters The mice returned from the longest distance, being caught at the same stumps where they first were trapped

This homing behavior is not so well developed in the field mouse (*Microtus*) as in the deer mouse, yet a large male returned to his home territory in an hour or less when removed 200 yards distant Further studies with this species suggest

that it has little ability to return to its homesite when liberated at distances of 300 yards or more [8]

By tagging a large series of bats, Mohr[9] has found that they are capable of returning 30 miles to the roosting site

The writer has marked red squirrels, liberated them slightly more than a mile from the home territory, and observed the squirrels in their normal haunts shortly thereafter The same may be said of Eastern chipmunks, which when released nearly 700 paces from their home quarters somehow managed to return without delay to the point from which they were first captured, although it is reasonably certain the animals had to invade territory quite unfamiliar to them

Territorial Behavior Studies have demonstrated that birds, at least during the breeding season, have certain well-defined territories, which are jealously guarded by the males Considerably less is known of territorial rights among mammals, but enough is at hand to suggest that a definite range is guarded by mammals as birds Many are acquainted with the aggressive nature of squirrels and chipmunks when their domain is invaded by a stranger of their kind Gordon[10] has remarked on the small territory occupied by pine squirrels (*Sciurus fremonti*) while gathering pine seeds The incessant churring calls of these squirrels, where their territories adjoin one another, has been likened to the singing of male birds to warn others that the singer was ready to defend its area against invasion Gordon further remarks that Douglas squirrels in Oregon have an even more circumscribed area, some covering not more than half an acre, and that these squirrels kept carefully within bounds but gave chase to any rival which entered their territory for food The writer has observed the Eastern chipmunk pursue and engage in a spirited fight with trespassing individuals which invaded its home domain During the breeding season, woodchucks will likewise pursue any of their kind which come near their burrow suggesting a defense of feeding and home territory which is not well marked during the late summer and fall, when

parental duties are past This defense of territory is probably not marked in such gregarious species as the prairie dog

During the season of reproduction, bull fur seals, reaching the hauling grounds before the females, select a section of the rocky shore and guard it with great vigor against any challenger Days before the arrival of their prospective harem, the big seals are torn and bleeding from many vicious fights and the encounters may continue long after their consorts have arrived and borne the single pup

American monkeys have a loosely knit organization, moving about from one area to another as the fruits on which they principally feed ripen Spider monkeys appear to travel in troupes of a male and several females and their young, but Carpenter[11] has recorded groups composed of males only Usually the larger groups break up as feeding activity occurs but it is said that the resultant smaller groups stay within sight or hearing of one another and all join together toward evening

Carpenter[12] has shown that howling monkeys have definite territories and remain within the boundaries of these from one year to another The monkeys may move from about 50 to 800 yards per day, but at times when food is concentrated they may feed in the same tree for several days As a group approaches the limits of its range, its course changes and it moves back toward the focus of its area One group with between 25 and 30 animals had a territorial range of approximately 300 acres No other clan of monkeys was found in this territory, although foreign individual males were at times seen here The movements of the group within the area are rather restricted and occur with reference to food and lodge trees The shifting and extending of range, according to Carpenter, are constantly occurring with particular groups

ACTIVITY

When the activity behavior of any species is carefully studied one notes that the movements of the animal are activated

by a number of factors, these often all combining to make for a rhythmic cycle which is little varied Probably the most potent factor which occasions movement is brought on by some internal urge Stomach contractions in the rat are rhythmic and are caused by hunger [13] These induce a general feeding activity by the rat The time at which animals are active has a direct bearing on all their other behavior This activity appears to be conditioned by environmental complexes

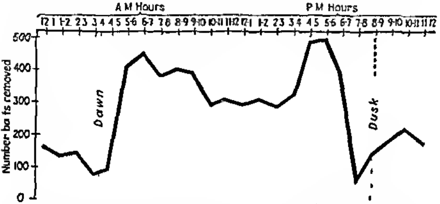


FIG 76 —Activity of the field mouse (*Microtus pennsylvanicus*) during the early summer is illustrated in this chart Several hundred stations in mouse runways were selected marked by stakes and a pinch of oak flakes placed in the burrow By making hourly visits for a 24-hour period and noting when the baits were removed an indication of the period when mice are most active is secured Greatest activity appears to be shortly after dawn and the hours preceding dusk

Few mammals are strictly diurnal or nocturnal With many species activity is greatest in the early morning and late afternoon, the brightest part of the day and darkest hours of night often being reserved for rest

Little effort has been made to study carefully the activity periods of wild animals Deer mice usually wait until darkness is complete before venturing from their nest and return to the home quarters before the pale of dawn When captive deer mice which had shown no activity other than during the night were placed in total darkness for a month, the same relation between activity and outside light persisted as at the beginning of the experiment The experimenter concluded that

the activity rhythm of the mouse is not produced by nor directly dependent upon a daily fluctuation of environmental conditions and so is to be considered an expression of an internal physiological rhythm Because of the definite nocturnal activity of deer mice and the deep-seated and fundamental nature of the rhythm, it seems logical to suppose that the most important environmental conditions which cootrol the activity of mice are those which prevail at night [14]

Field mice are about at all hours but appear more active by day Field observations indicate considerably more activity shortly after dawn and in the late afternoon (Fig 76) Predation possibly plays a selective part in determining periods of greatest activity, for vertehrate enemies do not appear to be so active at these periods [15]

Few diurnal species are equally active throughout the day Feeding and associated activity usually are most prominent shortly after dawn As mid-day approaches, the animals tend to rest They become active again toward dusk and continue so until early evening Squirrel hunters are so familiar with these traits that they find it unprofitable to hunt after the sun is well risen or before the afternoon shadows have lengthened

Strictly fossorial mammals which live the greater part of their lives underground seem not to have developed an activity rhythm When the broken earth which indicates the tunnel roof is pressed in by one s heel and the operation is repeated a number of times and for many different series of burrows, it may be observed that these are repaired equally at almost any hour of the day or night It appears probable from this that rhythmic activity, where well pronounced is an adaptation to meet the needs of the species in lessening predation

SOCIABILITY

An animal may be gregarious but this by no means implies that the species is sociable Many animals live in sizable

groups but lend little aid to individuals of that group which experience danger Ground squirrels of the prairie regions may number a dozen or more individuals to the acre but they live unto themselves The same may be said of bats, which often congregate in vast hordes but can scarcely be said to profit or utilize in any manner the proximity of numerous neighbors Nor do woodchucks, which frequently may number ten or twelve on a single hillside, exhibit the social customs which we customarily associate with their kindred relatives of the plains, the prairie dogs When these latter animals are alarmed by a hawk, coyote, or other predator the chippering bark of an individual will quickly send other members of the colony scampering to their burrows

Moreover, such species as the wolf, which leads a solitary life for much the better part of the year, often associate in packs of several during the periods of food scarcity, when their cooperative hunting is often necessary to bring down large game

Most monkeys are gregarious, forming a loose group organization Spider monkeys are usually to be found in small groups, either a mother and her young, a number of females with their respective young, one or more males with many females and their young ones, or males only Eventually these groups join with larger ones, so that they number 40 or more individuals Usually such a group breaks up during the early morning, but the members keep loosely in contact with each other by vocalization or may actually stay in sight of one another, although they appear to have no highly centralized social control Usually groups or herds are dominated by a single leader, but with these monkeys control is rather diffuse If a group is disturbed, the older animals rush to the place of disturbance, under such conditions rudimentary types of cooperation are to be observed [14]

Play The young of most mammals roll and frolic when small, but such playful traits disappear as the individuals become independent of their parents

Young wild monkeys of various species exhibit play patterns. The young run, jump from branch to branch, or may stand and jump up and down, swing from branches by means of their limbs or tails, or even play with sticks, leaves, and the cast-off hulls of fruits. The young of several monkeys wrestle, hug one another, or play alone, sometimes for hours. The usual play is of a social nature, the youngsters swinging, clasping one another, or actually chasing each other through the trees and nipping at the hindermost portion of the pursued. Fox and wolf cubs and kittens of the various wildcats tumble and bite one another as do their domestic congeners. The young of weasels play together in a manner strikingly reminiscent of young kittens.

With approaching maturity, such playfulness is less often observed, but some animals continue to play with one another long after they have attained full stature. No group exhibits this better than the tree squirrels, which may be observed chasing one another from tree to tree or spiraling madly up and down the trunk of some patriarchal oak. Such activity has no relation to the season of reproduction, for it may be observed when family duties are long past and there is no thought of raising another litter. Adult woodchucks and ground squirrels have been observed to indulge in a sort of play.

The famous slide of the otter is known to all American naturalists, and many have seen it in use. Selecting a relatively steep bank which leads into a pool, the otters, for there are usually several which indulge in such play, clear away sticks and other trash which might interfere with their mad dash. Often a snow bank is selected, and this, with the repeated tobogganing, becomes slick and slippery. The otter, its fore paws extending backward, slides down this incline, often a dozen yards long into the pool below. The bank is often too steep at the slide for the animal conveniently to scramble up and it must then make a circuitous route to gain the top of the slide. In the land of no snows, the otters select

a muddy or clay baok, Bachman[17] records these slides common in the reserve dams of the rice fields of Georgia Fourteen aoimals have been seen occupying a single slide at one time Seton, after collecting much testimony on the subject, is convinced that the exercise is indulged io for sport and fellowship alone and concludes that the act is removed entirely from the influence of sex or season He adds.[18]

> Whether the otter slides from the top of a mere snowdrift into the adjoining hollow, or down a muddy bank into a stream, or, best of all, down a long, icy hill, to plunge into deep, cool water below, it is evidently done for sport, for the joy of feeling itself flying through space without labour and without violence, and with the very same exhilaration that such a thing would give to mankind To this, the creature fails not to add the crowning charms of good company and of friendly rivalry, for, so far as I can learn, no one has ever yet seen an otter enjoying its slide alone

Intraspecific Cooperation That some species may aid their kind at critical moments in escaping a common enemy is evident from the following A young pika was observed to be closely pursued by a weasel, which followed the pika with amazing accuracy through the rock slides and crevices As the weasel was about to capture the fast tiriog pika, another pika cut into the race, keeping ahead of the weasel and just behind the exhausted pika, which dodged out of the death race at the first opportunity Soon a third pika joined the race, but was unsuccessful in diverting the weasel's attention from the second pika, which was showing signs of weariness Shortly a fourth pika joined in the exciting relay, which by this time had resulted in a very fatigued weasel The weasel shortly gave up the unequal contest The pikas apparently aid each other in such crucial moments in escaping a common enemy by forcing it to run a relay race against an overwhelming number of opponents[19]

Among monkeys, when a disturbance occurs, all the adults frequently rush to the scene, and under such conditions we might assume at least a rudimentary type of cooperation

Enemies, as the jaguar, have on occasion actually been pelted with such available weapons as were at hand

If danger threatens or the animals are alarmed, any member of a beaver colony will give a resounding whack with its great flat tail, thus warning other members of the clan These in turn spread the alarm in a similar manner. This action is probably involuntary, but it serves a useful purpose. Muskrats likewise give such a warning, creating a truly remarkable loud noise These shot-like reports on the still night air are taken up by others, until all within hearing take to cover.

Coatis hunt in bands through the tropical forests. Some range through the trees while others follow below, so that iguanas, a favorite food, dropping from their resting quarters above, fall easy prey to the coatis on the ground

Interspecific Relations Animals which are but remotely related occasionally band together for purposes which are not always apparent Several instances have been recorded which show a friendship between the fox and the larger game animals The red fox has been repeatedly observed to visit a herd of feeding caribou, run among them, and actually brush against the flanks of a resting stag Again a fox has played a sort of game with these big animals, leaping at their heads and being rebuffed by a shaking of the mighty antlers Observers agree that both animals appear to derive some enjoyment from the procedure A fox has been observed walking along a trail with mountain sheep, he jumping up and biting their faces in play and they butting him gently along in front

Property Rights Various methods are employed to indicate property rights and home territory. Bears, both grizzlies and blacks, often select prominent trees near the trails which they frequently use In the Western states, quaking aspen is often selected and the marks are readily seen on the light-colored bark When such a tree is approached, the bear stands on its hind legs, reaches as high as it can, and scratches or bites the bark so that prominent marks are left Many woodsmen believe that the marks are made only by the male and

that the largest bear, being able to make the highest marks, probably intimidates others, warning them to avoid the territory This hypothesis is not supported by facts, for it is well known that females as well make such signs Wolves and the larger cats are said to urinate or leave some manner of scent on their kills and likewise use convenient "odor posts," signalizing to interlopers that the territory is occupied, but writers often ascribe too much interpretive power to such signs without being fully aware of the true significance of such actions

CHAPTER XIII

DISTRIBUTION

No mammal is sufficiently elastic in its organization to cope with the wide range of climatic or other conditions which are found throughout North America. Each species becomes specialized for environmental conditions which are often narrowly and sharply defined. The animal communities of polar, temperate, and tropical America are quite unlike just as those of the desert and mountain tops differ.

Some mammals are much more adaptable than others and accordingly occupy an extensive area which embodies many diverse associations. Such is the masked shrew (*Sorex cinereus cinereus*), whose range encompasses an area in excess of 2 million square miles, extending from central Alaska and all northern Canada south to North Carolina in the east and New Mexico in the west. Within its range, this mammal mite, weighing scarcely more than a penny, occupies diverse ecologic niches, from the driftwood lined beaches of the Atlantic Coast to the coniferous forests and arctic Barren Grounds of northern Canada (Fig. 77). Within this extensive range so little variation occurs that examples from Alaska and Tennessee are accorded the same subspecific rank.

In contrast to this wide ranging form, consider the pocket gopher (*Geomys colonus*), whose distribution seems to include scarcely a dozen square miles of territory in southern Georgia.[1] Deer mice, individuals of which are restricted to an acre or

so in extent, have found the entire continent suited to their needs, and one race or another occupies an ecologic niche from Alaska to Yucatan and across the breadth of North America.

Many bats, not restricted as other mammals, range widely and some species have been recorded from nearly every state of the Union. Such is the silver haired bat (*Lasionycteris*) which occurs from ocean to ocean, from Mexico to the coniferous forests of northern Canada. The power of flight is character-

FIG. 77.—The map illustrates the extreme differences in range of two North American mammals. The area in black is occupied by the tiny masked shrew, *Sorex cinereus cinereus*. The dot enclosed by a circle in extreme southeastern Georgia is the limited range of a pocket gopher, *Geomys colonus*. Within an area considerably smaller than the confines of the circle four different forms of pocket gophers exist, none of which overlap the range of their kin.

istic of all bats. Still, some force acts to prevent the utilization of this power in extending the range of every species. The little Bailey bat (*Myotis baileyi*), from available records of collectors, appears to be restricted to a small region of New Mexico. The very irregular boundaries which delimit the range of any species are a testimony to the inexorable laws which prevent excessive spread of a species.

FACTORS INFLUENCING DISTRIBUTION

The range of any mammal is usually dependent on a number of very diverse environmental factors, some of which may be quite apparent, as water barriers to terrestrial species and

extensive tracts of land to aquatic species Others may be most obscure, as, for example, the chemical nature of the soil which influences plant life and, in turn, the animals dependent on such plants The presence or absence of water, extensive deserts, humid forests, mountain ranges with their attendant barriers of climate and vegetation, and many other factors contribute to the restriction in range of a species

Temperature Temperature undoubtedly is one of the most important factors in the distribution of life Its effect on both plants and animals is apparent at every hand Wherever arctic conditions prevail, relatively few species are found, under temperate or tropic temperatures, numerous forms exist and these are characterized by great diversity

One need not travel from the poles to the equator to witness this changing life A train will carry the traveler in a few hours from the humid eastern coastal ports of Central America, through dense jungle where sloths, monkeys, coatis, and agoutis abound, to the continental divide, a mile above sea level, where tree squirrels and native rats not unlike those of California and Maryland exist Many genera of mammals which are found near sea level in the United States occur in Panama only on the mountain peaks

Temperature Laws of Merriam Dr C Hart Merriam, after long experience as a field naturalist throughout North America, became impressed with the importance of temperature in limiting the distribution of plants and animals Previous to 1894, Merriam had mapped the boundaries of life zones, unit areas of distribution characterized by possessing peculiar genera of animals and plants By plotting isotherms on a large-scale map of North America, Merriam argued that those isotherms agreeing with the boundaries of the provisional life zones were the significant temperatures controlling the distribution of life within the zone

In 1894, Dr Merriam formulated laws of temperature control for the Northern and Southern distribution of terrestrial animals and plants Assuming that certain temperatures are

of critical importance to the northward distribution of an animal during the season of growth and reproduction he stated *Animals and plants are restricted in northward distribution by the total quantity of heat during the season of growth and reproduction*

To determine the critical phase of remperatures which limit the southward distribution of life, Merriam next selected the mean daily temperature of an arbitrary period of 6 weeks during the hottest part of the summer When these were plotted and isotherms drawn, they agreed with the southern boundaries of the life zones as conceived by him

The second temperature law is stated *Animals and plants are restricted in southward distribution by the mean temperature of a brief period covering the hottest part of the year* Climate alone, according to Merriam's thesis, is the primary limiting factor in the distribution of animals Temperature is the dominating force, but rainfall, with its attendant *humidity*, was considered by Merriam as a significant factor, and he later divided the three zones of the Austral Region into humid eastern and arid western portions

Temperature may be influenced by many diverse factors, all of which play a part in restricting the distributional boundaries of a species Warm ocean currents may bathe arctic shores (Alaska) and thus produce a winter climate distinctly less severe than that of an area 200 miles inland Every Eastern farmer knows that corn will grow faster on a dark rocky soil than on a light sandy one, other things being equal, for the former absorbs and retains more heat All plants, for that matter, respond to favorable soil conditions and these in turn may be attractive to animals

The transition between these zones is rarely abrupt, for they merge imperceptibly into one another Certain isothermal lines form the boundary of these zones Temperature is influenced by altitude, slope exposure, nearness to large bodies of water, and other factors beside latitude, elevated plateaus, mountain ranges, and land masses bordering large bodies of

water. Thus the isotherms in the Northern Hemisphere are often deflected southward.

To illustrate, in Eastern United States the Appalachian Mountains carry the fauna of New England and New York southward along the higher parts of this mountain chain as far as Tennessee A similar condition exists in Western America, where boreal forms reach Mexico and southern California,

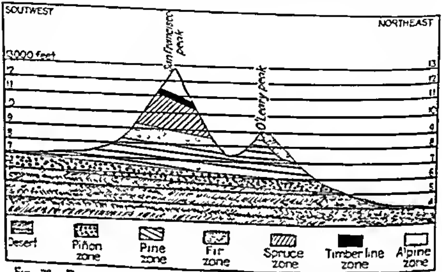


FIG 78 —Diagrammatic profile of San Francisco and O Leary peaks (Arizona) from southwest to northeast, showing the effects of slope exposure on distribution (*After Merriam*)

along the high peaks of the Rockies and the Sierra Nevada chains respectively In Western United States, slope exposure is an important determinant of temperature and consequently of the position of life zones In North America, any life zone commonly occurs at higher altitudes on slopes facing south than it will in level areas Moreover, the zones will be depressed on slopes facing north, where the total amount of heat received is much less (Fig 78)

Objections to the Life Zones of Merriam While Merriam's life zones[7] have been widely accepted by field workers, notably ornithologists and mammalogists, there are many valid

objections to the complete acceptance of such zones as based on temperature summing Some animals are absent from regions where temperatures during the season of reproduction are suitable for breeding purposes but winter temperatures do not permit survival, even though the species may be dormant Moreover, since little is known regarding the physiological responses of mammals to various temperatures, there seems little justification for selecting certain isotherms as the critical ones and excluding the rest, as Merriam did Kendeigh[3] after careful experiments concludes that maximum daily temperatures, rather than mean, are more important in controlling the southward distribution of birds and supposes the same is true of other animals

There are many other factors which, if not equally important as temperature, play an important role in the distribution of mammals The actual distribution of important and significant species is probably the safest measure for erecting life zones, and this concept has not been fully developed by Merriam Undoubtedly the life zones of Merriam offer a partial answer to the distribution of life in the mountain-dominated Western United States Here areas of great altitudinal diversity each have their peculiar animals and plants, often sharply delimited from neighboring associations of a higher or a lower stratum In Eastern United States, where relatively uniform conditions exist, life zones based on temperature summing alone are not in harmony with the known distribution of the various genera and species of mammals Dice,[4] in a discussion of the distribution of Alabama mammals, states

to many species The rivers about St Marys, in southeastern Georgia, appear to be a formidable barrier to the pocket gophers, as there are four distinct species of *Geomys* within a radius of 6 miles of this town, with no overlapping of ranges [5] Contrariwise, it is the lack of water which limits the spread of the Golden Beaver This big semi aquatic rodent is confined to the larger lowland streams of the San Joaquin Sacramento basin of California, its range stopping short of the heads of the tributary streams Its spread is barred westward by the Pacific and elsewhere by the mountainous nature of the region, untraversed by any waterway [6]

The great Colorado River forms an effective check on the dispersal of many mammals In its lower reaches where the river bisects the vast desert region of southeastern California, it acts as an insuperable barrier to a number of xerophilous rodents Such species appear to require a desert habitat and are seldom if ever, found in the riparian association which borders the river The river, as well as the intervening association of unfavorable habitats, constitutes the barrier to these species

Near its mouth, the river does not act as a barrier, even to non aquatic species By a shifting of its channel, as frequently occurs areas of bottom land are transferred from one side of the former channel to the other side of a new channel If these changes are of sufficient magnitude, and there is every reason to believe that they are species of the riparian association will be shifted thus preventing any homogeneity in the stock on either side of the river At least one pocket gopher (*Thomomys perpallidus albatus*) occurs on both sides of the river about its delta As one progresses farther up the river, prominent differences obtain between the mammalian fauna of each side despite similarity between climatic and floral conditions

E A Goldman found the white tailed ground squirrel (*Ammospermophilus leucurus leucurus*) and the Harris s ground squirrel (*Ammospermophilus harrisii harrisii*) inhabiting the

desert upland over wide areas flanking the western and eastern sides of the lower Colorado, respectively Desert dwellers as they are, neither extends into the lowlands subject to the vagaries of the river, but above the delta they both range on the mesas to the banks of the stream Near Parker, Arizona the two species live, each on its own side, only a few hundred feet apart At a point where the canyon is a mile deep, the strikingly different but allied Kaibab and Abert squirrels are found on opposite sides of the river, occurring in extensive yellow pine forests Many instances could be cited to illustrate how the Colorado River has functioned as an effective barrier for non aquatic and non volant species Even in its lower reaches, where there is no formidable canyon the river and its riparian association have long been an impassable barrier to xerophytic mammals

The mechanical and chemical character of the soil is of small moment to most species but the distribution of fossorial forms may be determined largely upon the nature of the soil Weak burrowers such as the kangaroo rats and pocket mice, must resort to regions of sandy soil or of soil of a loose friable character Moles are rarely found in heavy soils, shunning clays even though these be rich in food

appears to have little effect in limiting the distribution of these gophers

Food One often reads that the abundance of a certain species is dependent directly upon the amount of food available Sufficient and suitable food seldom appears to be a primary limiting factor in mammal distribution Even in seasons of great rodent abundance, the prolific species have little trouble in securing a sufficiency Nor is it lack of food which prevents the occupancy of an untenanted region bordering one which is well stocked with mammals This may be readily demonstrated in a woodland destitute of shrews, while neighboring wood lots may be well populated with these insectivores A cursory examination in either will show sufficient food to support many individuals

Cover Suitable cover may be of greater significance to a species than sufficient food The deer of northern Michigan Wisconsin and Minnesota often congregate during the winter in the protective coniferous stands During the night they forage out into the surrounding second growth hardwoods for browse and return to the warmer spruce or balsam stands to spend the day When the herds are sufficiently large a food shortage results and many deer starve rather than leave the protective evergreens for additional food, even though this be but a mile or two away

Shrews and wood mice are invariably more abundant in woods of which the ground cover consists of deep leaf mold and rotten stumps than in a similar stand barren of these requisites even though food be abundant in the latter The porous soil and decaying logs provide a sanctuary from enemies

A dry field with a protective cover of dead grass usually supports a higher population of voles than a neighboring area richer in food but lacking in a protective ceiling of matted herbage

Enemies The presence of large carnivorous predators probably has little effect on the distribution of smaller mammals

but irritating types, of which deer flies, botflies, and mosquitoes are examples, may play a significant role and make it utterly impossible for some species to invade otherwise promising territory A B Howell[8] states that the presence of quantities of horse flies kept the cattle entirely out of the higher Santa Rita Mountains of Arizona in the summer of 1918, although grass there was luxuriant and many of the animals had already starved to death in the foothills The territory affected was not considerable, but it might well have covered a much larger area The barrier to distribution in this instance seems to have been an irritant, the animals disregarding food and temperature and electing to remain in the foothills where conditions were far less propitious than on the higher mountain Caribou regularly make extensive journeys to find succor from the hordes of flies and mosquitoes, and undeniably the distribution of these animals in some parts of the arctic is determined largely by the presence or absence of insect pests Surely one of the greatest obstacles to habitation of the arctic by man is the hordes of vicious mosquitoes and flies which make human life miserable during the brief

dispar), almost identical externally, never becomes common? The answer is probably to be found in some inherent character of the species, difficult or impossible of analysis

In discussing theories of distribution, Howell[9] remarks

> We cannot reduce to a formula the existence of a species any more than we can that of man We may study the existence of a small group of individuals and arrive at a very few fundamental conclusions just as we can study a family of human beings but I judge that it is just as difficult to catalog in the order of their importance or to enumerate the factors involved in the distribution of the various forms of higher life upon this earth, as to so list the characteristics controlling the actions and reactions of each inhabitant of a city of large size

The Biotic Community The ecologist and biogeographer approaches the problem of distribution by recognizing a composite control of many factors, of which temperature is but one Species and their varieties, rather than characteristic genera stamp the zone or community According to Shelford[10] plant animal communities are grouped in a purely quantitative manner, in which all important organisms are evaluated on the basis of quantity and individual potency The ecologist attempts to discern the facts bearing on dynamic life relations of all kinds Of these, fluctuating populations, competition invasion, succession, and many other factors are considered when interpreting the distribution of life These major aggregations are considered as a biome, characterized by plant climaxes and many dominant animals To illustrate, the broad transcontinental coniferous forest is distinguished by its associations of spruce-pine, spruce balsam fir, and pine-hemlock Dominant mammals of this biome are the moose caribou, lynx, timber wolf, wolverine, and varying hare

HOME RANGE

No mammal roams indiscriminately over the territory in which it lives, for its range is determined by the presence or absence of food, shelter, and a suitable home Large mammals

have a wider range than smaller species, inasmuch as their alimental needs are obviously greater Flesh eaters range more widely than herbivores A weasel or mink may quarter over more than 100 acres in a single night, while a red squirrel or rabbit, finding suitable food in a small oak grove or berry thicket, will be content with several acres of territory

The seasons may bring need for more territory Wolves and foxes must range more widely during the periods of food scarcity, when much of their customary prey has hibernated or is protected by a blanket of snow Conversely, moose congregate in loose yards, sometimes 100 acres in extent but encompassing a smaller territory than is usually occupied during the summer months

It should be understood that the range of an individual species almost always overlaps that of its neighbor This is obviously true among small rodents and insectivores, where a hundred individuals may occur on the same acre Territory is recognized and defended among some squirrels, and it is not improbable that certain native mice defend their territory against intraspecific invasion Many of the larger carnivores will not tolerate others of their species within their domain but information is lacking as to the role they employ in staking out such territory as they may need Odor posts and claw marks on trees are suggestive of a warning to intruders

Home Range of Carnivores The territory of a mountain lion is fairly definite, being something of a circle which is covered by the lion at regular intervals of 3 to 10 days A male lion has been known to range over 100 square miles of territory but this must be considered exceptional The female lion if with cubs encompasses a range much smaller than her spouse but hunts her territory more assiduously

Wolves customarily assemble in packs of 6 to 30 during the winter and follow regular trails, which take the shape of a great uneven circle the diameter of which is often 30 to 50 miles The extent of this cruising radius is determined by the

abundance of game If this is plentiful, the circle may be small if game is scarce, it may be several hundred miles in length Hunting is easier in regions which have not been disturbed for several weeks and this undoubtedly accounts for the great range of some of these hunting trains [11] The summer range is of course much smaller and probably does not extend more than a mile or two from the home den in forested regions and scarcely more on the prairies

A red fox, when started by hounds will circle its own square mile of territory unless unduly pressed, when the harassed beast will enter unfamiliar terrain When the hounds are shaken the fox soon returns to its own homesite

Home Range of Herbivores The home range of the white-tailed deer is evidently small and under normal conditions it is doubtful whether the animal moves over an area greater than 1/2 square mile A buck and doe observed throughout several seasons in New York State seldom traveled farther than 3/4 mile in any direction from a small knoll upon which they frequently rested [12] It has been the writer s experience that the white tail is a sedentary creature, individuals remaining indefinitely in a spruce swamp or the adjoining hardwood ridges the total area of which did not exceed 200 acres Across northern Michigan, Wisconsin, and Minnesota deer in large numbers occupy small areas that have good cover but are lacking in sufficient food An abundance of food may exist less than a mile distant, yet large numbers will starve every winter Deer congregate wherever there is a good cover of thick evergreen growth without realizing that the food is insufficient to maintain the large herds which seek these

continually in the vicinity where it was first observed during the remainder of the summer In the following summer (1922) this same doe with bell attached was reported along the south rim of the Yosemite Valley During the summer of 1923 the same animal was reported many times from Little Yosemite Valley, a minimum distance of 17 miles from the place where it was first belled, and in the summer of 1924 along the Half Dome trail, about 4 miles north of its 1923 habitat Every winter the doe returned to Cascade[12]

Woodchucks have been known to swim a river daily to reach a choice food patch, but all who have observed this animal know it is seldom more than a rod from its burrow and rarely 50 yards distant Woodchucks will occasionally travel a distance of several hundred yards from their den to visit an orchard and feed on the drops, but these extensive movements for small rodents, usually are the result of an insufficient food supply within a few yards of their home quarters A chipmunk (*Tamias striatus*) has been observed to gather food regularly from a favored locality some 400 paces from its den while another traversed a broad gorge daily to reach an unusually favorable source of food Cottontail rabbits (*Sylvilagus floridanus mallurus*) are relatively sedentary creatures the females having a yearly range of about 3 acres and

entire life may be spent between several adjoining stumps in the woods

BIBLIOGRAPHY

1) Harper, Francis, 1927 *Proc Boston Soc Nat Hist*, 38(7) 340
2) Merriam, C Hart, 1898 *U S Biol Survey Bull* 10 3
3) Kendeigh, S Charles, 1932 *Wilson Bull*, 44 140
4) Dice, Lee R, 1923 *Jour Mammalogy*, 4 47
5) Harper, *op cit*, p 342
6) Grinnell, Joseph, 1928 *Univ Calif Chronicle*, p 431
7) Davis, W B, R R Ramsey, and J M Arendale, Jr, 1938 *Jour Mammalogy*, 19 417
8) Howell, A Brazier, 1924 *Ecology*, 5 52
9) *Ibid*
10) Shelford, Victor E., 1932 *Wilson Bull*, 44 144
11) Olson, Sigurd, 1938 *Ecology*, 19 168–170
12) Schoonmaker, Walter, 1932 *Jour Mammalogy*, 13 504
13) Bryant, Harold C., 1924 *Jour Mammalogy*, 5 201
14) Dalke, Paul D, and Palmer R Sime, 1938 *Trans Third N Amer Wildlife Conf*, pp 664-668
15) Hamilton, W J, Jr, 1937 *Ecology*, 18 255 263

CHAPTER XIV

USEFUL MAMMALS

The value of our native mammals in providing sport for the hunter pelts for the fur trade and meat for our people has been referred to elsewhere These are tangible values providing healthy outdoor recreation for many thousands of Americans and offering still others an opportunity to make a partial livelihood Mammals play other useful roles no less

There is a growing army of hunters who have discarded the gun for glasses and camera, who realize in a fine picture the thrill which can never be obtained from a mounted head, however handsome it may be More and more do we find sportsmen traveling to the north country for the sole purpose of obtaining moving pictures of big game

Henderson has adequately summarized this growing interest in our wildlife He states [1]

> The esthetic value of mammals is recognized in the laws for their protection in our great public play grounds the national parks where hunting injuring or destroying the wild animals is strictly prohibited not because of their intrinsic value but in order that they may be seen by visitors In consequence of their immunity from molestation they become very tame and seeing them in the open adds to the delight of thousands of visitors annually
>
> Automobile tourists crossing the continent on vacation tours are delighted at every exhibition of wild life along the route—prairie dogs on their mounds barking at the passers by jack rabbits bounding over the plains ground squirrels scurrying to their holes tree squirrels chattering among the trees an occasional coyote loping over the distant slopes and great is the rejoicing at a rare glimpse of a deer or antelope

WHALING

The pursuit of whales has occupied the attention of sea faring men for centuries Whaling in America was largely confined to the coastal stages, when vessels from Newfound land, Nantucket, and New Bedford scoured the adjacent seas Later these vessels sailed the oceans of the world, and the United States owes much to the intrepidity and fearlessness of the hardy whalers who first carried the Stars and Stripes into new and little explored corners of the world

By the middle of the nineteenth century nearly 700 vessels were engaged in the whale fishery of America The pursuit of whales was carried on so assiduously that not infrequently 25 or more vessels would be in sight of one another at a time Whale oil was much in demand for both ointment and the manufacture of candles until petroleum was first used for lighting when the whale fishery suffered reverses Today less

whaling is carried on in the North Atlantic and North Pacific than formerly, the decline of whales due to intensive hunting making their pursuit less profitable.

Modern Whaling. Modern whalers are equipped with a powerful gun mounted high in the bow, which shoots a 100-pound harpoon, the cap of which contains an explosive. A time fuse is provided, which sets off the explosive a few seconds after the harpoon has struck the whale. As it explodes long barbs are thrust out from the tip to fasten the whale securely. Often several shots are necessary before the whale is disabled and can be towed to the ship's side. A chain is passed out over the shank of the whale, just above the flukes. The animal is then towed to the factory. The whale is drawn onto the ramp and cut into various pieces, placed in vats and boiled down for the valuable oil.

The whaling industry, while not of such importance today as it was once, is by no means insignificant. Most whales are now taken in antarctic waters, particularly the dependencies of the Falkland Islands, and these have within recent years (excluding Japan) accounted for nearly two-thirds of the world's production.[2] Pelagic whalers have increased the take of whales in some oceans. These are large craft such as reconditioned ocean liners. They are provided with a ramp in the hull, and the whale may be drawn directly into the ship. The smaller boats ("catchers") bring their catch to the larger vessel, which is equipped to render the whale.

Improved methods of hunting and handling the catch of whales and utilizing the by-products make whaling still profitable to those engaged in the industry. The fleet of whaling vessels and floating refineries returning from the South Seas in 1930 brought the largest cargoes of sperm oil and by-products *ever loaded*, obtained, it is said, from whales which were located and reported by wireless-equipped airplanes and killed by electric harpoons. One vessel brought 62,000 barrels of oil and another brought 37,000 barrels.[3]

Products of the Whale Fishery Whale oil is the most important article obtained in the whale fishery A single large whale may yield over 200 barrels of oil This oil is used chiefly for soapmaking and for fuel oil Sperm oil is much more valuable and is obtained from the huge head cavity of the sperm whale Large males may yield 16 tons of oil but the usual take from an average whale will scarcely exceed 6 tons The sperm oil is used chiefly for lubrication of light machinery

Whalebone (baleen) was at one time very valuable, $1 a pound being paid for good-quality plates It is trimmed of its bristles, boiled until soft, and cut into the desired strips Its many uses have now been supplanted by steel, but milliners and dressmakers still find use for it [4]

The flesh of whales is eaten in Japan, and, to a limited extent, elsewhere The residue from the factories finds a ready sale as fertilizer

Ambergris is a fatty, dull-colored substance, occurring as a biliary concretion in the intestines of the sperm whale Lumps of various sizes are found floating in the sea, on the coast, or in the sand of the beach It is greatly valued in the perfumery trade High-grade ambergris will fetch $14 to $20 an ounce Lumps vary in weight, but there is a record of a lump weighing 750 pounds, all taken from one whale by the crew of a Nantucket ship Murphy [5] states that the total production in the United States in 1922 was only 44 pounds, which was landed at New Bedford and brought $11,000

THE SEAL FISHERY

The hair seals of the North Atlantic have provided an important industry for Newfoundlanders Each spring, in early March, the sealing fleet leaves St John s to journey to a vast continent of ice, to pursue and take the abundant harp seal and the rarer hood seal

Harp seals, because of their great numbers, are most sought by the sealers These slim graceful animals, seldom

exceeding 6 feet in length and 300 pounds in weight, have coarse hair which is of little value for the fur trade When scraped of its hair, the resulting hide is transformed into a soft lustrous leather which has a ready demand for the manufacture of handbags and wallets The thick layer of fat, when rendered, produces an unusually pure clear oil, which is widely used as a fine lubricant Of late years, the coat of the whitecoats or baby seals, being silky and white, has become fashionable for ladies wear

The hood seal, due to its comparative scarcity, is of much less importance in the seal fishery These seals are a saving grace when the vessels fail to encounter the whelping ice of the harp seals The coarser pelts do not give such fine leather nor can the oil distilled from their blubber compare with that of the harp seal Nevertheless the much larger size of the hood seal makes the hunt for them not wholly unprofitable

Seal fishery has been pursued for many years, but the picturesque days of sail are gone Formerly the windjammers with full sails, set out together for the great ice floes where these migratory seals congregated to whelp No longer do they race back to St John s with their loaded hulls Steel ships, wireless, and the use of airplanes to scout the whereabouts of the main patch or communal birthplace of the harp seals are important to the industry The industry has declined, but the valuable oil is still much in demand and vessels still sail each spring to the ice fields

SOIL CONSERVATORS

The efforts of wild animals in checking soil erosion and conserving water have been little appreciated until recent times Since the nation has become soil-conscious, conservationists have been increasingly aware of the part played by the beaver in regulating water flow and preventing hasty runoffs and consequent floods The beaver has long been successful in reclaiming soil, and his hydraulic engineering

feats merit considerable attention by those who would minimize soil erosion.

The impounding of water by dams provided sizable ponds where the beaver could build his home and store food for winter use. Eventually these ponds became silted, forming broad meadows, which were in turn succeeded by dense stands of alders, willows, and birch. Long before this succession reached its climax, the beavers had moved on to establish new sites, and the cycle was repeated.

Attention has recently been called to the importance of beaver dams as geologic agents.[6] It is believed that beavers have, in the past, aggraded all smaller valleys below the size of navigable rivers. Inasmuch as these big rodents have been active for many thousands of years they must be important physiographic agents. Their work is characterized by complete aggrading of valley floors, originally in small descending steps, which disappear in time and leave a gently graded, even valley plain horizontal from bank to bank. It thus seems probable that beavers have been responsible for the fine silt gathered in these valleys, which has produced the rich farm land in the valleys of the wooded areas of the northern half of North America.

The beaver has been enlisted as an ally of the Soil Conservation Service in its soil- and water-conservation program. A single example of the effectiveness of this animal is sufficient to illustrate its importance.[7] Overgrazing and logging had produced a situation in the upper drainage basin of Mission Creek near Cashmere, Washington, which allowed heavy runoff of water, resulting in serious floods in the valley below. Large numbers of valuable orchard trees had been washed out and other orchards were covered with rocks, soil, and debris.

where the beavers had formerly occupied only a few hundred feet of stream there were now 60 dams in more than 5 miles of waterway Now many, if not most, of these mountain streams vary in their flow with the seasons of the year During the spring runoff, the streams reach near flood proportions and do considerable damage Until mid summer a good flow is main tained, but eventually the flow is diminished, and there is insufficient water for irrigation purposes, with resultant drought conditions Both state and government agencies have constructed large water impounding dams at great expense to remedy this condition With the thought that beavers could regulate the flow by virtue of their many dams, a number of beavers have been introduced into areas where flood and drought conditions annually prevail These animals have proved most effective in their efforts In the lower Yakima Valley of Washington, beavers introduced from a point 60 miles away constructed several large dams, one of which was 90 feet long and 7 feet high and was blocking a stream flowing 65 second feet of water The storage capacity behind the dam was 691,500 gallons A man made dam similar to the one described would cost $2,500

Although the work of burrowing rodents on bare soil or on slopes may cause incipient erosion, their good services in soil turnover has long been recognized Pocket gophers are confirmed burrowers, their tunnels threading the ground in every direction at relatively uniform depths of from 4 to 8 inches Grinnell[8] has made a careful survey of pocket gopher activity in the Yosemite Park of California Measurements of earth cores reveal that the gophers were bringing to the sur face 1 64 pounds of soil per square yard Assuming that gopher workings covered only 0 1 per cent of the land surface in the area studied, there would be 3 6 tons of earth put up per square mile, or 4,132 tons over the whole park in a single winter Assuming that as much dirt is brought up in the summer, it is revealed that about 160 carloads of 50 tons each is lifted a distance of 8 inches every year

Such soil disturbance by gophers is by no means restricted to California or other Western states Every visitor to Florida cannot help having noted the amazing number of mounds piled up by these diggers The white sand mounds, often as large as a felt hat, are strikingly evident on the darker surface, and their incredible number attests the abundance of these animals Mounds each containing several pounds of dirt may often number a hundred to the acre

What of this soil turnover? How does it affect the terrain at large or react upon the vegetation and animal life?

Some of these relations of the pocket gophers to their environment have been outlined by Grinnell

1 The weathering of the substratum is hastened by the burrow systems carrying the air and the water and contained solvents to the subsoil particles and rock masses below

2 The subsoil is comminuted and brought to the surface, where it is exposed to further and increased rate of weathering

3 The loose earth brought up and piled on the surface of the ground thereby becomes available for transportation by wind and water, rain and melted snow carry it from the slopes down to fill up glacial depressions and to make meadows of them, and, when these are full, the sediment is carried on still farther by the gathering streams to contribute to the up-building of the great and fertile valleys beyond the foothills

4 Water is conserved for the reason that snow melts more slowly on porous ground than on hard packed soil or bare rock, so that the spring runoff is retarded and the supply to the streams below is distributed over a longer period of time, furthermore, the porous soil retains the water longer than packed ground and gives it up with corresponding slowness Spring floods are less likely to occur and a more regular water supply is insured to the lowlands

5 A porous, moist soil produces a fuller vegetational cover—forest, brushland, and meadow—and this again favors water conservation

6. The ground is rendered more fertile through the loosening of the soil as well as through the permeation of it by the tunnels themselves, thereby admitting both air and water to the roots of the plants The mineral constituents of the soil become more readily available and the rootlets are better able to penetrate the earth

7 The accumulated vegetational debris on the surface of the ground is eventually buried by the soil brought from below by the gophers and becomes incorporated to form the humus content so favorable to the successful growth of most kinds of plants Grinnell concludes that on certain wild lands the burrowing rodent is thus one of the necessary factors in the system of well-being.

In addition to the factors set forth above, the accumulation in soils of the excreta, hairs, horns, and dead bodies of mammals, together with stored foods and nests which are not used or eventually deserted, may loosen and enrich the soil [9]

FERTILIZER PRODUCERS

The droppings of wild animals have long been utilized for enriching the soil Bones are occasionally collected, these being eventually ground up and used to enrich the soil.

The guano of bats has been more extensively used than that of other wild mammals. Bailey gives a full account of the rich deposits in the Carlsbad Cavern of New Mexico.[10] In this extensive cavern the free-tailed bats (*Tadarida mexicana*), which are noted for their habit of roosting in extensive colonies, are much prized for their guano deposits. In late summer and early fall the bats gather in tremendous numbers to pass their long winter sleep in the recesses of this cave. So dense are the streams of flying bats as they enter the cave that they may be seen for a distance of 2 miles, and these flights continue from late afternoon until well after dusk. Their numbers run into the millions.

The enormous guano deposits in the cave have reached a depth of 100 feet, as many feet wide, and ¼ mile in length. A

flourishing business occupied the guano collectors from 1901 to 1921 Bailey states that during a 15 year period half of each year was devoted to the work, generally from September to March, and that from one to three carloads of guano weighing about 40 tons each were shipped each day From 20 to 40 men were employed at a time sacking, elevating, and hauling the guano to the railroad, and night and day shifts were worked in the cave Prices ranged from $20 to $40 a ton Now there is little guano left in the caves The guano is deposited at the rate of about 1 inch a month so that it is obvious that many years must pass before a commercial quantity can again be established

In Santa Cruz County, California, wood rats are numerous and build their large houses, often 6 feet high, the basements of which may contain several bushels of excrement In some instances there may be 10 or even 20 sacks of this manure of purely vegetable origin Local florists gather hundreds of sacks of this manure and ship to neighboring cities It is considered very beneficial for plants which require an acid soil, such as ferns [11]

DESTRUCTION OF PESTS

The role of mammals as insect destroyers has been overshadowed by birds, but some groups rank with our avian allies in reducing insect populations Inasmuch as availability almost invariably determines what an animal will eat, insects must reach significant proportions before mammals are attracted to such prey

Some mammals, notably the bats feed almost exclusively on insects, and where these mammals occur in large numbers it is said that their reduction of insects is considerable On Indian Key in Tampa Bay, Florida, bats are abundant and mosquitoes are rare or absent On adjoining keys, where the bats are scarce or absent, mosquitoes abound and this has been attributed to the absence of bats [12] Because of their supposed role in reducing malarial mosquitoes, it has been thought

advisable to encourage bats in malaria-infested regions. Bat roosts have been erected about San Antonio, Texas, to attract the Mexican free-tailed bat. A few roosts have been occupied, but there is little evidence that these bats have been influential in reducing the numbers of malarial mosquitoes.

Shrews and moles consume quantities of insects and may be important factors in reducing the numbers of injurious forms. Shrews feed upon various small animals, but their most important food appears to be insects. McAtee[13] states that the short-tailed shrew has proved to be one of the principal enemies of the larch sawfly and it has been ascertained that in New Brunswick 40 per cent of the cocoons are destroyed by this shrew. Moles are known to feed on the grubs of Japanese beetles, so reducing these pests that almost complete control obtains in small areas.

Although it is generally recognized that rodents do not restrict their feeding activities to plants, the highly insectivorous nature of many species has only recently been established. Western ground squirrels are notoriously fond of insects. This is particularly true in the irrigated portions, where grasshoppers are often a scourge. At times the striped ground squirrel seems to prefer grasshoppers to any other food, and where these insects are abundant it will eat them almost to the exclusion of all other foods.[14] In Iowa ground squirrels have been noted to feed extensively on cutworms, webworms, wireworms, grasshoppers, and many other noxious insects. Prairie dogs have been observed to jump into the air to catch the passing hordes of low-flying grasshoppers, and it is well established that tree squirrels of all kinds relish beetles, caterpillars, and such grubs as they may find beneath the bark or hidden among the fallen leaves.

Wild mice are inordinately fond of insects, which often comprise a large share of their food The little insectivorous grasshopper mouse (Fig. 49) subsists largely on insects, scorpions, and other small creatures. In examining several hundred deer mice taken during the summer, the writer has

found a good proportion of the stomach contents to contain insects Graham[15] has shown that one of the important factors of environmental resistance tending to hold down the numbers of the larch sawfly is the effect of mice These animals open and destroy on the average about 60 per cent of the larvae that succeed in spinning cocoons In a collection made near Itasca Park, Minnesota, he found that out of 481 open cocoons of the larch sawfly 74, or 15 per cent, had emerged normally, 382 cocoons, or 80 per cent, had been opened by mice, 15, or 3 per cent, had been parasitized by insects, and 10, or 2 per cent, had been destroyed by fungi Observations in years following these first studies confirm the importance of deer mice in reducing the abundance of the larch sawfly

The carnivores are important consumers of insects, some of which are serious crop pests The most notable insect eater of this order is the skunk, which at some seasons appears to feed on little else, McAtee[16] refers to its good services in this fashion

> Of our large mammals, skunks certainly are the greatest enemies of insects Army worms, tobacco worms, and white grubs are favorite prey of these animals In Manitoba, Mr Norman Criddle, field officer, Canadian Entomological Service, estimated that on one 8 acre tract skunks destroyed 14 520 white grubs to the acre Cutworms, the potato beetle and grasshoppers and other insect pests are eaten by skunks, and the common eastern skunk once proved so efficient an enemy of the hop grub in New York, that the first legislation protecting the animal in that state was passed at the demand of the hop growers Investigation in New Mexico by the Biological Survey showed skunks also to be most important natural enemies of the range caterpillar

Skunks are particularly partial to white grubs and cut worms These animals are soon attracted to areas infested by grubs They proceed to dig a hole, root out the grub, and continue to comb an area until the pests have been much reduced or eliminated

Foxes, coyotes, badgers, bears, and many other flesh eaters rely on the insect world to sustain them during much of the

year Their perpetual warfare against insects is one of several reasons why these little creatures do not completely populate the earth

BIBLIOGRAPHY

1) Henderson, Junius, and Elberta L. Craig, 1932 "Economic Mammalogy," Springfield, Ill, p 9
2) Borley, J O, 1932 Encyclopaedia Britannica," 23 555
3) Henderson, Craig, *op cit*, p 32
4) Borley, *op cit*, p 554
5) Murphy, Robert Cushman, 1933 *Natural History*, 33 303
6) Ruedemann, Rudolf, and W S Schoonmaker, 1938 *Science*, 88(2292) 523-525
7) Scheffer, Theo, 1938 *Soil Conservation*, January, pp 178-180
8) Grinnell, Joseph, 1923 *Jour Mammalogy*, 4 143-145
9) Taylor, Walter P, 1935 *Ecology*, 16 134
10) Bailey, Vernon, 1928 "Animal Life of the Carlsbad Cavern, Baltimore, pp 108-114
11) Streator, Clark P, 1930 *Jour Mammalogy*, 11 318
12) Fargo, William G, 1929 *Jour Mammalogy*, 10 204
13) McAtee, W L., 1926 *Smithsonian Rept for 1925*, 416
14) Burnett W L, 1914 *Office Colo State Entomologist Circ*, 14 8
15) Graham, Samuel A, 1929 *Jour Mammalogy*, 10 196
16) McAtee, *op cit*, pp 416-417

CHAPTER XV

INJURIOUS MAMMALS

Any mammal may be of considerable value in one locality and highly destructive in another Field mice, when they occur in meadows and uncultivated lands, seldom destroy sufficient vegetation to affect man On the contrary, their very presence in such places provides predatory birds and mammals with an important source of food The birds of prey may feed exclusively on field mice when these voles are abundant, permitting other small but desirable species to maintain their numbers or actually to increase

Predatory mammals, many of which are important fur bearers, likewise feed on these mice and refrain from destroying the more desirable game species Thus the voles serve a most useful purpose On the other hand, when voles occur in the orchard, their feeding activities result in much damage, particularly to young fruit trees the bases of which they may girdle An entire orchard may be severely damaged in a single season by the action of these mice

The snowshoe rabbit might be cited as another example of a species which provides a very positive economic value It is a splendid game animal and is so favored by Eastern hunters that attempts have been made to reintroduce it where changing environmental conditions or overshooting have resulted in a decreased population Moreover like the mice it acts as a buffer species in providing the larger predatory mammals

with food when they might, in the abseoce of these hares, be attracted to game more desirable from the viewpoint of man On the other hand, it has repeatedly been shown that snow shoe rabbit control is essential in certain habitats before natural reproductioo and plantations of some tree seedliogs may be successful

Pocket gophers in the alfalfa field, irrigation canal, or truck garden are potential pests and are likely to cause much damage In the mountains, they are said to be an important soil forming agent and a real benefit to plant life, couoter acting tbe deleterious soil packing effect of cattle and hoofed game [1] Thus it is evident that the cootrol of a species by man, within reasonable limits, may be justified at a given time aod place, whereas its increase might be eocouraged in aoother locality, not far removed, at the same time

It is esseotial that those entrusted with the control aod reduction of mammal populations take cognizance of these facts aod every effort be made to establish a complete history of the species before efforts are made to lessen its numbers Dire coosequences may result from hasty conclusions aod campaigos against any species unless the facts of the case have been carefully examined by unbiased investigators

DAMAGE TO CROPS FORAGE AND FORESTS

The annual loss to agriculture and forestry caused by native mammals in the United States has been placed at \$200 000,000, which presumably is a conservative figure By far the larger share of this loss may be levied against pocket gophers, ground squirrels, field mice, cottontails, jack rabbits, and prairie dogs, with cotton rats porcupines woodchucks, moles, and otber species adding to this destruc tion Bell[2] has pictured this loss graphically when he presents the following estimates submitted by various states for the fiscal year 1917, listing the losses to crops Montana, \$15,000,000 to \$20,000,000, North Dakota, \$6,000,000 to \$9,000,000, Kansas, \$12 000 000, Colorado, \$2 000,000 California,

$20,000,000, Wyoming, 15 per cent of all crops, Nevada 10 to 15 per cent of all crops, or $1,000,000, New Mexico $1,200,000 loss to crops and double this amount to range Bell believes that native rodents cause a loss of $150,000,000 a year in the United States in cultivated crops and a similar loss in forage on the pasture ranges, making a total loss of $300,000,000 a year from this source

Field Mice The short tailed voles (*Microtus*) are found in favorable localities throughout the United States, and wher ever they occur in sufficient numbers in agricultural regions damage to crops usually results, often to an appreciable extent These mice are cyclic, occurring periodically in great numbers, so that they are always a potential menace to crops Agriculturists usually ignore the presence of these animals until damage is apparent when the ubiquitous little rodents have become extraordinarily abundant

The most serious charge against field mice is their destruc tive habit of girdling the roots and trunks of fruit trees (Fig 79) In years when mice are abundant, the damage may be unusually severe, and entire orchards have been destroyed or the trees so weakened that little hope of recovery may be anticipated During the winter of 1935–1936 the Eastern field mouse became excessively abundant, not locally but over a wide area encompassing the entire Northeastern United States, from Maine to Virginia westward to Wisconsin The damage to New York orchards alone was placed at $500 000 [3] A single county in the Shenandoah apple belt of Virginia suffered an estimated loss of $200,000

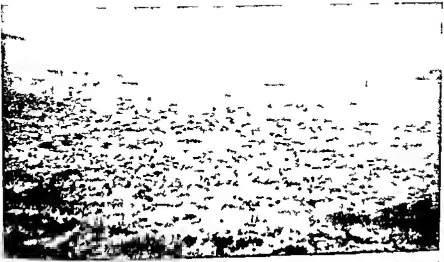
Field mice do not limit their destructive habits to fruit and shade trees In the famous 1907 Humboldt Valley out break in Nevada, mice were estimated to have reached a high peak of 12,000 to the acre and their ravages brought devastation to parts of the valley The yield of hay was reduced by one-third, potatoes and other root crops were largely destroyed, and the damage to alfalfa by the destruction of the long rootstocks was irreparable Piper[4] estimated the

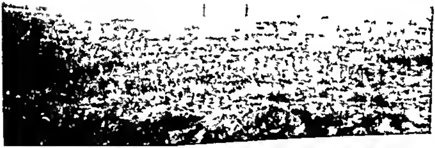
loss, on the basis of hay, alfalfa, and other pasturage, root crops, and trees at $20 per acre, amounting to a damage for the whole valley at $300,000 The loss in hay fields and pasture land is less spectacular and hence easily overlooked, although mice are often abundant enough to take a measurable toll Inasmuch as these mice will eat their own weight of green

Fig 79 —This twenty year-old apple tree has been completely girdled by field mice Dirt has been removed about the base to show the extent of the injury Bridge grafting may save the tree When field mice are abundant they often devastate an entire orchard and cause extensive damage and expense to the orchardist

food daily, a usual population of 50 or more mice per acre can take an appreciable toll Field mice frequently invade the garden, and, with their cousins, the pine mice, make severe inroads on potatoes and tuber-rooted plants It is often necessary to reseed sizable plots when these pests are at all common

Pocket Gophers The worst mammal pest of the Western agricultural lands is the burrowing pocket gopher Pocket





been placed at more than $12,000,000,[5] and there is much evidence that the numbers of these destructive rodents are increasing. During the last few years of drought, gopher damage has been more noticeable on grazing lands, particularly in the mountain meadows where moisture and vegetation have been more plentiful.[6] The gopher is particularly severe in the Middle West, where alfalfa is grown without irrigation. The roots and parts of the stem are eaten, and, in addition, mounds from the subterranean burrows are thrown up which effectively cover the growing plant and later obstruct its harvest. As many as 1,500 distinct heaps of earth to the acre have been counted on fields of average infestation. So abundant are these mounds in the river valleys of the Middle West that one may walk across an entire tract by stepping from one pocket-gopher mound to another.[7] Meadows may have the appearance of having been plowed, owing to the mounds and workings of these animals. It is obvious that the gophers must be reduced on such lands before a crop of hay can mature (Fig. 80).

Pocket gophers frequently girdle orchard trees, which may produce grave results. In a 60-acre Oregon cherry orchard it was found that 71 per cent of the trees had been killed and 21 per cent were injured beyond recovery, leaving less than 8 per cent of the trees uninjured. In badly infested apple orchards, 60 per cent of the trees were either dead or badly injured.[8] Citrus grove owners in the Southwest have suffered from gopher activity, and ornamental trees such as palms have been quite ruined by the industry of this rodent. Even lawns are not exempt from the ravages of these burrowing beasts.

Rabbits. Rabbits and hares are widely distributed over North America and wherever they occur do a certain amount of damage. This is particularly severe during the winter, when herbaceous plants have died and grasses and other low-growing plants are covered by snow. Snowshoe hares have been known continually to eat back the tops of firs,

one tree having been eaten annually for 46 years before a shoot could grow beyond the reach of the rabbits [9] Bryant[10] has charged the jack rabbits and cottontails with the loss of entire crops in some fields of California Jack rabbits, when they occur in small or moderate numbers in the Southwest may have a neutral or even beneficial status on the range They seldom appear to consume more than 3 per cent of the potential production of grass on the range [11] Their size makes them a potential menace, for 12 1 California jack rabbits will eat as much as a sheep while 60 6 jack rabbits will consume as much as a cow The sheep jack rabbit and cow jack rabbit equivalent for the larger Allen jack rabbit is much less

In the mountains of Utah the snowshoe rabbit is very common and extensive damage is often noted in natural coniferous stands as well as in plantations made by the Forest Service In some of the denser areas of reproduction less than 10 per cent of the trees are free from injury, and a fairly large proportion are so severely injured as to be of slight future commercial value [12]

The introduced European hare (*Lepus europaeus*) is a potential menace to crops and orchards wherever it becomes established It is most abundant in western Massachusetts and Connecticut and in the Hudson Valley of eastern New York In such places this big hare invades the orchards and when deep snows permit, the loss to fruit growers is severe The losses in a single New York State county exceeded \$100 000 during the winter of 1915–1916

Ground Squirrels The widely distributed and numerous ground squirrels exact a fearful levy on cultivated crops and cereals This is particularly pronounced in the West where entire grain fields may be partially destroyed One of the worst offenders is the Columbian ground squirrel (*Citellus columbianus*) Shaw[13] observed that the squirrels commence feeding on the leaves of winter wheat in March As the stalks lengthen the squirrels bit through the juicy

growing up, eventually attacking the wheat heads One squirrel will destroy 56 pounds of wheat, worth more than a dollar Inasmuch as there may be several squirrels to the acre and populations numbering 25 per acre have been destroyed, it is apparent that this is a pest of major importance

The flickertail (*Citellus richardsoni*), is an unmitigated nuisance in the prairie regions of North Dakota Bailey[16] records their destructive habits in this manner

> As soon as they emerge from hibernation in spring they begin digging up the seed and eating the young grain that has been sown in the fall and as soon as the spring sowing starts they dig up the new seed and carry it away When the grain sprouts they dig both sprout and kernel and after the kernels are entirely exhausted they feast on the young growing grain until it is headed out when they begin on the young heads cutting down the stalks and eating the young seed through all its growing stages As soon as the grain is ripe they carry it away as rapidly as possible to their storehouses and this is continued until the last bundle is removed from the fields Four thousand of these squirrels on or around the edge of a section of land would remove a considerable portion of the crop and it is not surprising that they are considered the greatest pest of the region They seem to have no preference between wheat rye barley oats or flax, but take whatever is nearest their dens

Small wonder the annual loss in grain crops in North Dakota has been estimated at $6,000,000 to $9,000,000, in addition to $100,000 to combat their ravages

Prairie Dogs It has been oft repeated that the grass consumed by 32 prairie dogs is equivalent to that required by one sheep and that 256 prairie dogs require as much vegetation as that eaten by a cow One can scarcely visualize the devastation of these rodents if their extensive colonies and crowded mounds on the prairies have never been seen The tremendous dog towns of 40 years ago have ceased to exist, but the prairie dog is far from extinct, its numbers still remaining such that from Texas to North Dakota and over much of the Great Plains region it remains a problem Federal investigators have shown that prairie dogs in northern Arizona destroy 60 per

cent of the dropseed and 83 per cent of the grama grass, or 80 per cent of the total potential annual production of forage This in itself is serious enough, but if such destruction occurred in the recent drought years the results might well be calamitous

With the settlement of the country and the utilization of the range by cattle, early stockowners experienced disastrous losses from these rodents The prairie dog is preeminently a social animal, and its vast colonies sometimes encompass thousands of square miles In 1900 a Texas colony measured 250 miles one way by 100 to 150 miles the other, covering an area estimated at 25,000 square miles Of course, this area was not entirely populated by the prairie dogs, but where they are abundant the holes may number 100 per acre and often average 25 to the acre Merriam[15] estimated the population of prairie dogs in the great Texas colony at 400,000,000 The grass annually eaten by these rodents in this extensive colony would support 1,562,500 head of cattle In sections where these rodents are abundant, the annual loss is said to range from 50 to 75 per cent of the producing capacity of the land and to aggregate millions of dollars

Cotton Rats In Southeastern United States one of the most abundant rodents is the cotton rat (*Sigmodon hispidus*) They may at certain times become extraordinarily abundant Five hundred rats have been killed by poison on a single acre of sweet potatoes Cotton rat damage to sugar cane is severe, 36 per cent of the crop sometimes being destroyed and in some instances as much as 78 per cent In southern Florida truck farming is an important industry, and every type of produce here raised is subject to damage by the cotton rat In 1924 the damage amounted to $45,000 in the 12,000-acre tomato crop, while in 1931 it was estimated that the loss to all truck crops amounted to $150,000 in spite of control measures by the farmer Three or four plantings of squash are frequently necessary before even a partial crop may be raised, sweet potatoes are often so badly damaged that they have no market value,

and the best of the winter tomatoes are often ruined by the rodents[16]

Cotton rats are equally destructive in Texas, where they destroy the cotton plants, vegetable crops, and other cultivated crops In fact, wherever they occur their numbers increase to amazing proportions and they must then be reduced or otherwise extensive damage may result

Moles Moles are generally credited with being largely insectivorous, seldom resorting to plants Logical assumption has it that field and pine mice, traveling in the runways of moles, must be charged with such damage as results to bulbs, tubers, and farm crops generally As a result of extensive damage to flower bulbs in the Pacific Northwest, Moore[17] concludes that tulip, tigridia, and bulbous iris bulbs, together with a long list of other plant foods, are taken readily by the big western mole (*Scapanus townsendi*) For many cultivated plants this mole shows acquired tastes which are not influenced by a deficiency of supposed natural foods As such, it may become a major pest to the extensive and important bulb industry of the Northwest The mole is a potential carrier of plant pests and diseases, and the activities of these animals may seriously increase damage during disease outbreaks Moles have been accused of spreading such disease organisms as the mosaic virus and bacteria The mole may become an intolerable nuisance through its habit of upridging the soil and disfiguring lawns and golf courses, the latter being expensive to restore Moles are difficult to eradicate by persons unfamiliar with their habits

Woodchucks In parts of the East where they are numerous, woodchucks frequently cause considerable damage to vegetable gardens They are particularly fond of sprouting peas, beans, and other succulents and may waddle along an entire row of sprouting vegetables, completely devouring the young shoots These big rodents may number several individuals to the acre for extensive areas and in alfalfa and clover fields they destroy considerable both by direct feeding and by despolia

tion of plant life by their huge mounds In addition to their actual feeding, woodchucks riddle fields with their tunnels, their stone-filled mounds are a menace to the mower, and, in addition, they are often a serious pest to young fruit trees during the early spring

Kangaroo Rats and Pocket Mice Some ranchmen complain more bitterly of the depredations of kangaroo rats (*Dipodomys spectabilis*) than of those of any other mammal Normally the rancher suffers but little from the activities of these beautiful desert rodents, but when periodic lean years recur and drought prevents growth of any grass, rodent damage may be a critical factor in determining whether a given number of livestock may be grazed on the area Vorhies and Taylor[18] have this to say regarding the kangaroo rat

> With two kangaroo rats to the acre (1,280 per square mile), there would be 64,000 animals on the 50 square miles of the Range Reserve If each rat stores 4 pounds of grass seeds and crowns and other edible forage during the season (and in severe seasons we find that more crowns are stored than under ordinary conditions) a total of 256 000 pounds, or 128 tons, of edible forage are rendered unavailable to stock In dry years it is probable that this amount of forage would be of critical importance allowing 50 pounds of food a day for each steer, the forage destroyed would be sufficient to provide for the needs of one steer for 5,120 days, or for the needs of 14 steers for one year On a stock ranch the size of the Range Reserve this might mean the difference between success and failure

cut the heads from the stalks to feed upon the ripening grain, sometimes cutting 40 to 50 per cent of the stalks in patches of considerable extent. Rarely total loss of the crop has been reported.[20]

Porcupines. The porcupine feeds chiefly upon the bark of various trees. In the Western states, their winter diet consists chiefly of the bark of western yellow pine and juniper. By injuring and destroying young forest trees, they may become a major nuisance in forest areas. The injury occasioned by these big rodents often results in weakened bushy-topped or spike-topped trees useless for commercial purposes. In some areas 100 per cent of the young growth is thus damaged. Where porcupines are abundant in national forest areas, their control is imperative, for they will destroy 90 per cent of the seedlings, and, through continued girdling of young trees fifteen to twenty-five years of age, will destroy all chance for commercial timber for many years to come.[21] Porcupines have been known to destroy completely large stands of plum and cherry trees and damage severely apple trees by eating off the leaders.

Mountain Beavers. In the mountain regions of the Pacific Northwest the mountain beaver (*Aplodontia*) does not materially affect man's interest, but with the increase of cutover lands the animal seems to have flourished and now has invaded regions where its presence is undesirable. By destroying clover and meadow grasses, garden truck, and berry bushes, these animals have become of some economic significance. Forest saplings are frequently trimmed or topped and may suffer injury from which they cannot recover.

Deer. Although the deer population of the Eastern states was not so many years ago at a low ebb, efforts to encourage and increase these game animals have been rewarded. Indeed, their numbers have reached such proportions that they constitute a serious problem to those entrusted with reforestation. In the Pennsylvania forests, where conditions have been unusually favorable for natural reforestation following fires, the land might well be considered barren, for during the past

quarter century no timber crop has become established Careful study indicates that this condition may be directly attributable to the overstocked deer herds, which do not permit the young trees to become established In many parts of Pennsylvania the deer have exhausted the food supply to such an extent that there are deer lines through the forest showing that they have eaten all vegetation for a height of 5 feet above the ground [**] Such conditions may be found sparingly in other Eastern states Other than this extensive damage to forests, deer have within recent years invaded agricultural lands in some numbers and have been responsible for much damage to young orchard trees Not infrequently the leaders of young apple trees are eaten back, this condition continuing for several successive years until the young tree dies Damage to buckwheat and vegetable crops is at times rather extensive

trees and pilfer some fruit but seldom commit any consequential damage Beaver often flood areas and the stands of forest trees may be drowned over extensive areas, but the good services rendered by these big fur bearers more than counteract any destructive tendencies they may indulge Flesh eaters, as raccoons, skunk, and occasionally foxes frequently eat fruit and vegetables The raccoon may cause considerable mischief by feeding on corn while in the milk stage, tearing down and destroying far more than it can eat

Introduced Rats and Mice As destructive as our own native rodents may sometimes become, none can compare with the brown or Norway rat (*Rattus norvegicus*), an alien said to have been brought to this country by the Hessians during Revolutionary times Indeed, it is doubtful if any animal the world over can share honors with the rat in its destructiveness Rats are said to cost residents of the United States $200 000,000 a year and a less conservative estimate places this figure at $2 500 000,000 [24] The rat is particularly destructive to growing corn and various grains in the shock, rice, sugar-cane, and truck crops Melons and tomatoes are particularly susceptible to attack, the rats destroying far more than they eat So fond of fruits and berries are they that extensive journeys are made for these delicacies In a single afternoon one man shot 28 rats from the branches of a cherry tree growing in the heart of Washington, D C Food in storage is particularly liable to damage and not infrequently a major share of the stored crop is destroyed

Because of their small size, house mice are less destructive than rats, but their numbers sometimes increase to such a point that they may become a real pest During an outbreak in Kern County, California the dry bed of Buena Vista Lake swarmed with them, and the mouse numbers were placed at 82 280 per acre [25] Fortunately in this large irruption little of value to man was damaged, but it is not difficult to visualize the damage such rodent numbers are capable of should the outbreak occur in a city or farming community In fact such

outbreaks have occurred periodically the world over, and house mice have been abundant enough at times actually to kill sheep and destroy colossal amounts of grain, making what they did not eat unfit for human or stock consumption

DESTRUCTION OF LIVESTOCK AND POULTRY

On the Western range, where extensive herds of cattle and sheep occur, predatory mammals may take exasperating toll of the livestock Wolves, coyotes, mountain lions, bobcats, and bears have been harassed by the stockman, intent on reducing such losses, and an extensive campaign has been waged against these "outlaws by federal and state hunters for many years Under these conditions the wolves and bears have been much reduced and in some instances completely eradicated from range country Coyotes persist and appear to increase in the face of this continued persecution

preceding 5 months 20 yearling steers, 9 calves, 1 cow, 15 sheep, and a valuable sheep dog. In two weeks at Ozona, Texas, two wolves destroyed 76 sheep.

In Oregon, four coyotes in two nights killed 15 purebred rams valued at $20 each. One flock in Morgan county, Utah, was attacked by three coyotes and $500 worth of sheep were killed in an hour. Near Antonito, Colorado, 67 ewes, valued at about $1,000, became separated from the rest of the herd and two days later all were found killed by coyotes.

One Texas bobcat killed over $300 worth of Angora goats, and another in a month had killed on a single ranch 53 rams, 1 ewe, and 1 goat. In New Mexico a grizzly bear was killed which had destroyed 32 head of cattle during the spring and was known to have killed 50 cattle the previous year. An Arizona hunter, while following the trail of a mountain lion which was later shot, found the bodies of nine head of cattle which had been killed by this animal.

Most of the instances related above were the work of especially destructive animals, and wolves, coyotes, wildcats, and bears generally should not be blacklisted for the misdeed of a few of their kind. The good services of these predators in ridding the range of destructive rodents, direct competitors with livestock for range grasses, must not be overlooked.

The simplicity with which undesirable predation may sometimes be checked is illustrated in the following account. An Oklahoma farmer had been troubled by coyotes killing his chickens. He claimed that when the corn got high enough for their cover, coyotes lay in wait for chickens in the early morning along the edge of the field, and that he had as many as ten killed by one animal in a single morning. By the simple practice of keeping his chickens enclosed until 11 o'clock he experienced no further loss.

Foxes, skunks, and weasels occasionally raid the hen house, but their destruction of poultry is insignificant contrasted to that of the rat. One rat killed 190 chicks in a single night, rats ate the legs off 40 young black ducks on a game

farm and a single rat destroyed, in three nights 120 pheasant chicks [23]

MAMMALS AND EROSION

Overgrazing by sheep and cattle in the national forests of Western America has resulted in much lessened grass stands, and these have been succeeded by coarse herbaceous thick rooted plants Such vegetation is peculiarly attractive to the pocket gopher, which rapidly invades new territory as sufficient food becomes available Pocket gophers have become an increasingly important problem in the West, where efforts to check their ravages have not been altogether successful Some of the meadows of Western parks become so honeycombed by the burrows of these rodents that livestock, deer, or elk break through at every step This hastens the process of erosion and prepares the soil for the washing which attends the heavy thunder showers so characteristic of Western mountains That the problem is a real one is attested by the support given the control work by stockmen, who have no proprietary interest in the land allotted them for grazing A range examiner of the Forest Service has the following to say regarding the effect of rodents on erosion in the Boise watershed of Idaho [29]

siderable wastage, causing periodic flooding of crop lands, or delaying the proper irrigation of crops These rodent-caused breaks not only result in loss of crops through failure of irrigation water but are often responsible for incipient gullies which eventually result in the loss of considerable productive land A break was caused by a pocket gopher in an Idaho irrigation canal that carried 18,000 inches of water for the irrigation of 30,000 acres It cost $5,000 to repair the break and while the ditch was being put in serviceable condition the drought resulted in the loss of 25 per cent of the crops

When prairie dogs colonize on hillsides, their denudation of vegetative cover and burrows prepare the way for the start of sheet erosion In the Cochetopa Forest of Colorado erosion has completed destruction initiated by the work of prairie dogs Even the tiny field mouse, by its burrowing and tunneling, may cause severe washing of the soil During heavy downpours, water rushes into these surface burrows forming tiny rivulets which if on a slope, soon enlarge to form gullies The writer recalls that these mice were responsible for considerable damage to roadside embankments in New York State where the burrows acted as a conduit for rain water and eventually caused extensive cave ins

MAMMALS AND DISEASE

It is not generally recognized that wild animals often transmit virulent diseases to man and his livestock Epidemic disease not infrequently occurs among rodents and large game mammals, the severity may be such that large populations are leveled The study of the disease of wild animals is still in its infancy but it is known that man and his domestic animals may come in daily contact with these diseases When outbreaks of rabies foot and mouth disease or tick fever break out among wild species, it has been found necessary in the past to conduct extensive extirpatory campaigns against these animals Such wholesale slaughter is regrettable but inevitable when considerable monetary loss or a threat

ened human pandemic appears imminent During the 1924 outbreak of hoof-and-mouth disease in California, more than 22,000 deer were poisoned on the Stanislaus National Forest The disease was checked, and the deer have since regained their former abundance

Tularemia, or rabbit fever, is a debilitating and often fatal disease, which is transmitted from wild rabbits, woodchucks, opossums, muskrats, and other species to man by the wood tick It is rather widely established in the United States, where about 500 cases are reported annually, 5 per cent of which prove fatal Tularemia has likewise proven fatal to sheep

United States, and the mortality in parts of Montana is over 70 per cent Mortality in Maryland and Virginia cases exceeds 20 per cent Spotted fever is an infection of rodents and certain small carnivores Ground squirrels are particularly important hosts of the Rocky Mountain spotted tick, which transmits this often fatal disease Formerly it was thought that the tick fever was restricted to the mountainous areas of the West, but the disease is now known to have a much greater distribution In the East, the American dog tick, Eastern carrier of spotted fever, is most abundant along the coast and

FIG 81 —A pine mouse with a number of engorged nymphs of the American Dog Tick (*Dermacentor variabilis*) attached around the head The short tailed mice are important hosts for this tick which is the eastern carrier of Rocky Mountain Spotted Fever (*Photograph by Bureau of Entomology and Plant Quarantine*)

has been found chiefly on dogs In addition, deer mice, field mice, pine mice, jumping mice, house mice, cottontails, swamp rabbits, cotton rats, Norway rats, squirrels, shrews, and moles have been found to harbor this pest (Fig 81) For many years tick fever took its tragic toll of cattle, but where the original quarantined area once exceeded an area of 728,565 square miles, the part now under quarantine is reduced to 25,392 square miles In central and southern Florida, however, it has been observed that tick fever of cattle is of the tropical variety and that it flourishes on deer The deer thus would appear to constitute a serious obstacle

to the eradication of tick fever in these parts It now seems likely that the deer must be materially reduced if tick fever is to go in Florida Such a reduction might conceivably have a disastrous effect on other wildlife For instance, the Florida cougar probably feeds largely on deer, as the related species is known to do in Western America Will the eradication of the deer spell doom to the few mountain lions which still exist in tropical Florida?

An outbreak of rabies in Western America in 1914–1915 caused tremendous loss to livestock and resulted in many human fatalities A single rabid coyote caused the loss of 27 steers In parts of Oregon, Idaho, California, Utah, and Washington, cattle and sheep were destroyed in large numbers and at least 1,500 people were bitten by rabid animals During the first year of the rabies epizootic, the loss to live stock was set at over $500,000 in Nevada alone, and the total loss to stock during this outbreak was placed at $5,000,000 [31]

bounty, and shooting have all been employed as repressive measures in the control of injurious rodents and predatory mammals where this seems desirable

Spencer has succinctly stated the problem in the following manner [39]

> Control of mammals and birds that cause economic losses is one of the most perplexing problems in the wildlife field This is because of the widespread opinion that an impassable rift exists between the interests on the one hand of the farmer, stockman, poultryman and forester, who seek protection for their stocks, and on the other those of the conservationist, who deplores sweeping reductions of any form of wildlife In the last analysis, how ever all are of one mind regarding the desirability of conservation of wildlife resources The farmer, once his means of livelihood is not endangered by losses chargeable to wildlife, becomes the mainstay of the wildlife conserva tion program In fact, wildlife is the heritage of the landowners Until research develops adequate means of preventing damage by certain animals however, the farmer and rancher must continue to control them by reduction Support of plans for game increase can hardly be expected until management of game is so perfected that crops will not be endangered

Poison While there are multiple objections to the use of poison as a control measure, it is by far the cheapest and the most efficient known agent for dealing with many injurious mammals, particularly the rodents During an outbreak of bubonic plague in California, the United States Public Health Service reduced the ground-squirrel population about 90 per cent through the distribution of poisoned baits Campaigns against these squirrels were conducted over an area of 3,373,146 acres, the average cost of labor and materials totaling 17 4 cents per acre and the average infestation of ground squirrels being about 6 5 squirrels per acre Nearly 22,000,000 ground squirrels were said to have been destroyed, and the menace of plague was entirely relieved

Field mice in Eastern orchards may be entirely eliminated by the careful distribution of poisoned apple cubes directly in their runway The writer has seen no evidence which points to the destruction of useful animals through this control

practice, and the rodents are effectively controlled at a cost of approximately $1 an acre

Fields with severe pocket gopher infestations, where the animals number 10 or 15 to the acre, can be treated rapidly, one man effectively poisoning all burrows on a 40- to 60 acre tract in a day In 1919 federal and state agencies guided farmers and stockmen in the destruction of prairie dogs and ground squirrels on more than 18,000,000 acres of farm and range lands Parties organized by the United States Biological Survey, aided by labor contributed by cooperating farmers were successful in destroying most of the prairie dogs and ground squirrels on approximately 1,000,000 acres of the public domain The magnitude of these control operations may be visualized when we learn that 132,000 farmers and stockmen joined in the campaign and 1,610 tons of poisoned grain were distributed on infested lands The estimated savings of these farmers amounted to more than $11,000,000 in a single season Farmers reported in many cases a crop return of $15 to $20 for each dollar invested in the control work and a notable increase in the stock carrying capacity of the ranges [33]

been expressly distrihuted for coyotes, only eight had been killed.

Hall reckons that $10,000 was lost through sheer waste by one man engaged in poisoning coyotes in Nevada.[34] Several years ago porcupines in the forests of Pennsylvania became destructive to trees and a salt-strychnine preparation was distributed by crews of young men not particularly trained or qualified for such work. It is said that a number of deer were attracted to the salt and met death when they ate the preparation. If trained biologists had been entrusted with such a campaign, it is questionable if any deer would have been lost.

Gassing. The use of various gases has been widely and successfully employed in control of burrowing rodents. This method has been unusually effective in reducing prairie-dog and ground-squirrel infestation and is, within limits, selective. As an illustration of its cheapness and effectiveness, one man treated a 320-acre plot harboring prairie dogs with carbon bisulphide at a cost of $9.79. More than 2,000 prairie dogs are estimated to have been killed and the pasture salvaged was enough to support eight head of cattle. Carbon bisulphide has proved particularly effective in California in the bitter extirpatory war against ground squirrels. The liquid, which volatilizes easily, is pumped into the hurrows of the squirrels by means of a special machine or is poured on waste balls and thrust into the entrances of the hurrows and these closed with a bit of sod. In the Eastern states calcium cyanide is used extensively for woodchuck control. The powder on exposure to air gives off the deadly hydrocyanic acid gas. The powder is thrust on a long-handled spoon far down into the burrows or blown into the den with a gas gun. Carbon monoxide is used less often. A long hose attached to the exhaust of a tractor or car and placed into a rodent burrow proves singularly effective.

The use of gas may prove a menace to other wildlife. Several years ago county-wide campaigns in New York were conducted against woodchucks, which had become unusually

numerous The writer, who at the time was conducting a fur survey, was dismayed to find that, following these campaigns, the skunk catch declined greatly, less than half the numbers being taken about the farm lands where woodchucks had been destroyed This again illustrates the need of careful supervisory leadership in any campaign, no matter how pressing and immediate the need may be for control of rodent pests The value of the skunk as a fur animal and as a rodent and insect destroyer probably balanced the damage occasioned by woodchucks in these areas

extent that not only have they kept the animals under control in their home areas, but many are following coyote trapping as a profession and have cleaned up areas adjacent to their homes A seventeen-year-old farm lad caught 85 coyotes by trapping during the season when the pelts were prime A fifteen-year-old boy trapped 26 coyotes in 14 months [35] This successful method, encouraged by the Game Commission, shows what can be done in coyote control without killing many valuable dogs and useful wildlife through the use of poison

Bounties The payment of bounties has been extensively employed to control injurious rodents and predatory mammals The practice has met with little success, for in no instance does it appear that a species has been satisfactorily controlled by this method In order to be effective, bounties must be high enough to insure the destruction of at least a majority of the individuals the first season, but no state has been able to maintain such a high bounty for more than a few months

Moreover the bounty system is peculiarly susceptible to fraudulent practices As an example, a Midwestern state placed a bounty on ground squirrels, the tail alone being sufficient evidence to claim the bounty Boys trapped the squirrels alive in the spring, cut off their tails, and permitted the animals to go free, only to breed more tail-bearing squirrels for bounty

Where a state bounty is sufficiently high, trappers in neighboring states have shipped skins to their friends to collect these bounties Indians have skillfully dyed ground squirrel skins and passed them off as coyote pups

It has yet to be demonstrated that the reduction of predatory mammals through the use of bounties has had any material effect in increasing the game species In Ontario, the wolf and coyote population is said to be greater now than a decade ago, but during that period 33,000 wolves were destroyed at a bounty cost of $500,000 It is interesting to note

that deer have greatly increased both in number and in range in Ontario at the same time that the wolves and coyotes were increasing It seems likely that had the money spent on bounties been used to find out what the game and fur resources of Ontario need, and to meet that need, the province would have accomplished some good

It seems unbelievable that states still consider bounties of any value in ridding themselves of noxious or supposedly injurious animals With two centuries of bounty trials in this country and the almost complete failure of every attempt to control wild animals by this measure, one would think the system would long since have been discarded Such does not appear to be true

Shooting Shooting is an effective and not too costly means of control for many rodents and, to a lesser extent, the larger predatory species It is selective and thus has a decided advantage over poison and traps In Eastern United States it has been the writer's experience that woodchucks may be controlled rather well with a rifle This practice adds an element of sport and can be depended upon to reduce materially the woodchucks on any farm where they have become too numerous

Ground squirrels are hunted throughout the Midwest when their numbers become too abundant and are much reduced When jack rabbits become a pest to the range, shooting has proved equally effective as poison and somewhat less expensive, for the animals may be destroyed at a cost of 0 033 cent per rabbit as against 038 per rabbit when poison is used [34] California paid a bounty on mountain lions for many years but finally employed a state lion hunter to keep these big cats from becoming too abundant All accounts indicate that the state-hunter system is a most desirable one

Other Control Methods Many methods other than those outlined have been used for the repression of undesirable mammals Some are rather ingenious, while others are of little worth and fail utterly to control the proposed victim

Drives have been carried on in the West for many years The impressive list of casualties pictured from time to time in the press would lead the inexperienced reader to believe that such drives are unusually effective A jack rabbit drive at Fresno, California, in 1893 resulted in the death of 20,000 hares Other drives at the close of the last century netted 5,000 to 10,000 jack rabbits Usually such drives are an excuse for a holiday Schools are closed, business generally suspended, and men, women, and children take part in the proceeding Coyotes are occasionally made the target of a drive, a wide circle of hunters perhaps a dozen miles across converging on a given point and the few miserable animals shot

In parts of California where extensive damage to crops by deer have resulted, the method of exclusion by the use of deer fences has proved satisfactory These fences are of woven wire, with several strands of barbed wire attached to the posts projecting above the fences proper The fences vary in height from 7 to 9 feet and appear to be effective in excluding deer from orchards and other agricultural lands [31] Coyotes, wolves, and wildcats are sometimes excluded from sheep pastures by fencing with 3 foot woven wire, a strand of barbed wire between it and the ground, and two strands of barbed wire, 6 inches apart, above the woven wire fence This would be effective in reducing sheep mortality from dogs in the Eastern states, where such losses are prevalent, but the cost is often prohibitive

Repellents have been used to prevent rodent injury to fruit trees, but few have proved successful Creosote oil and coal tar, in the proportion of 1 to 2, undiluted lime-sulfur solution, paint, and various oils have been used with only moderate success The chemical composition of the preparation may injure the tree severely Sulfonated linseed oil mixture has been used in Minnesota, but no repellent has been generally adopted Moreover, injury from pocket gophers and field mice, two of the worst enemies of fruit trees, is largely subterranean

and repellents will not penetrate to the root surface where they might prove effective in reducing such injury

Bacterial viruses have been extensively adopted in Europe where their successful use has brought much praise Little success has attended their use in this country, and the Bureau of Biological Survey has discouraged this practice Storer[38] censures the use of so called virus or bacterial cultures He feels that not only do they fail to reduce the rodents for which they are intended, but they sometimes spread the infection to man Some rodents may become carriers of the infection (usually *salmonella* of the paratyphoid group) and contaminate food later eaten by human beings

In Pennsylvania the exclusion of deer from experimental plots and forest stands has been effected by the use of electric fencing Two wires one 22 inches from the ground, and the upper 15 inches higher, are insulated with old inner tubing After the deer once nose the wire and receive their initial shock, they as a rule avoid it The fences were better than 90 per cent efficient in preventing deer from entering experimental plots [39]

17) Moore, A W , 1932 *Jour Mammalogy*, 13 36–38
18) Vorhies, Charles T , and Walter P Taylor, 1922 *U S Dept Agr Bull* 1091 36–37
19) Burnett, W L., 1923 *Colo Agr Coll Circ* 39 12
20) Scheffer, Theo, 1938 *U S Dept Agr Tech Bull* 608 13
21) Young, Stanley, P , *1936 U S Dept Agr Bur Biol Sur Leaflet* BS-54, 27
22) Clepper, Henry E , 1931 *Commonwealth of Penn , Dept Forests and Waters, Bull* 50 17
23) True, Gordon H , Jr , 1932 *Calif Fish and Game*, 18(2) 141
24) Holsendorf, B E , and P W Clark, 1937 *U S Pub Health Service*, Suppl 131 1
25) Hall, E Raymond, 1927 *Calif Univ Publ in Zoology*, 30(7) 192
26) Bell, *op cit* , p 295
27) Jackson, H H T , and H Warfel, 1933 *Publ Univ Okla Biol Surv* , 5(4) 68
28) Hamilton, W J , Jr , 1936 *Cornell Ext Bull* 353 6
29) Young, *op cit* , p 4
30) Bishopp, F C , 1935 *Smithsonian Rept for 1933* p 393
31) Bell, *op cit* , p 294
32) Spencer, Donald, 1938 *U S Dept Agr Bur Biol Surv Leaflet* BS-115
33) Bell, *op cit* , pp 431–432
34) Hall, E Raymond, 1930 *Jour Mammalogy*, 11 365
35) Johnson, Floyd A , 1935 *Hunter Trader Trapper*, September, p 39
36) Vorhies, and Taylor, *op cit* , p 577
37) Storer, Tracy I , and Gordon H True, Jr , 1930 *Calif Fish and Game*, 17(3) 266–269
38) Storer, Tracy I , 1933 *Univ Calif Agr Ext Serv Circ* 79 6
39) Gerstell, Richard, 1938 *Penn Game News*, 8(12) 8–9

CHAPTER XVI

GAME MAMMALS

THE big game mammals of North America are among the most spectacular and abundant of the entire world At one time threatened with extermination, the antelope, elk, and other species have increased amazingly during the present century and few sportsmen fail to see a suitable number when afield

We are realizing more fully, too that these grand animals are not for the hunter alone but can and must provide enjoyment to the camera enthusiast and nature lover alike Adequate steps have been taken in nearly every state and province to provide proper protection As a result, not a few states are faced with the embarrassing predicament of having too much game, a condition which has been of no little concern to game officials In many Eastern states and in California, and perhaps elsewhere, deer have become abundant to the point where their destruction of crops has necessitated a reduction in the herd It seems far more desirable to have such a state of affairs than to be a nation destitute of this rich natural heritage a condition forestalled only by the militant efforts of conservationists everywhere

A glance at Table 1,[1] adapted from government and state censuses, is sufficient to show those states which lead in the production of big game mammals During 1938, field officers of federal land administrative agencies, National Park Service Grazing Division, and the Forest Service, as well as state game

and conservation commissions, all aided in making the nation wide survey The estimates are admittedly far from accurate but give a basis for future surveys As a result of the study, 31,121,675 white-tailed deer, 1,271,196 mule deer, 231,905 black tailed deer, 165,764 elk, 13,346 moose, 131,555 prong horned antelope, 16,953 bighorn sheep, 13,267 mountain goats, 81,270 black bear, 1,108 grizzlies, and 43,722 peccaries were counted, giving a total of well over 5 million animals Most of this big game may be found in the national forests or on state and private lands

VALUE AS A FOOD SUPPLY

Anderson[2] believes big animals still play an important role in the economics of arctic America These animals serve as a source of food and clothing for natives, explorers, and pioneer settlers, but are little used for trade Even now the large game species furnish the greater part of the food supply of Indians and Eskimos in extensive areas It is said that most of the Eskimos depend largely upon caribou skins for winter cloth ing and sealskins for boats and that most of the Indians use moose skins for moccasins Game permits the native popula

1938 BIG GAME INVENTORY OF THE UNITED STATES
Indicating states where large game is most numerous

White-tailed deer	Michigan Pennsylvania Minnesota Wisconsin Texas New York Maine
Mule deer	California Colorado Utah Oregon New Mexico
Black tailed deer	California Oregon Washington
Elk	Wyoming Montana Idaho Colorado Oregon
Moose	Minnesota Wyoming Montana Maine Michigan
Antelope	New Mexico Wyoming Oregon California Nevada Idaho
Rocky Mt Bighorn	Wyoming Idaho Colorado Montana
Desert Bighorn	California Arizona Nevada Utah
Mountain Goat	Washington Montana Idaho
Black Bear	Washington California Oregon Minnesota Idaho Colorado

tion to live in a region which would not support human beings were the wild life exterminated. Even today settlers, prospectors, and the native population depend on the Alaskan caribou for their fresh meat, and when these wandering herds fail to appear in their regular migrations the natives suffer hardship.

As a nation, Americans are great meat eaters, individuals eating the equivalent of their own weight annually. Obviously in areas of dense population, only a small share of this supply is obtained from wild mammals and in the aggregate their value as food is probably not too great. Nevertheless the food value cannot be dismissed too lightly. In 1938, Pennsylvania hunters killed 127,000 deer, chiefly does, the average dressed weight being about 80 pounds. This meat totals 10,160,000 pounds and at a conservative value of 15 cents per pound would be worth $1,524,000. In normal years the kill seldom exceeds 40,000 animals, but even this is a sizable return in tangible values. California hunters take about 21,000 deer each season, 29 949 deer were killed in Wisconsin in 1936, Oregon hunters shoot between 10,000 and 13 000 a year, 4,770 elk and 2,713 deer fell before guns in Montana during the 1938 season, and in the same year Michigan nimrods were bagging 40,000 bucks. None of the returns are complete, however, and far more game is killed than reported. Eight states (Pennsylvania, Michigan, California, Minnesota, Wisconsin, Maine, Oregon and New York) have yielded more than 190,000 deer annually to hunters in recent years. Other states where the deer are not so abundant undoubtedly bring this total to 250,000 animals, whose combined dressed weight, at an average of 130 pounds each, is valued at $5,000,000.

Second only to the deer in meat value, the rabbit millions are sold in Southern and Western markets in large numbers during the fall and winter months. Ten million jack rabbits are killed annually in North Dakota, more than a million rabbits are shot annually in Wisconsin, 2,849 000 rabbits and

hares were shot in Pennsylvania during the 1938 season, more than a million are killed in New York annually, and hunters from other states claim equally large numbers It is not improbable that 50,000,000 jack rabbits, cottontails, and varying hares are shot each year in the United States Valued at 25 cents each, the meat value would be $12,500,000 Add to these two favorites the millions of squirrels and other wild mammals utilized for food, the meat value for the nation undoubtedly approaches the $18,000,000 mark Most of this meat is utilized, for the animals are usually killed during cool or freezing weather Even so, Americans are hardly dependent on this food supply, except those in outlying regions or the natives of Northern latitudes, to whom it is most important

GAME MAMMALS OF NORTH AMERICA

White-tailed Deer The white-tail (*Odocoileus virginianus*) is the most important and abundant big game mammal in North America A century ago its importance to the settler was great, for it supplied him with a ready supply of meat and its hide made durable jackets and other articles of clothing With the settlement of the country and the pushing back of frontiers to make way for agriculture this deer has increased greatly in numbers The white-tail and its allies have a very wide distribution, extending in the East from James Bay and New Brunswick south to Florida and in the West from British Columbia and Oregon south into Arizona, New Mexico, and entire Central America It is a lover of the forests and swamps and continues to maintain its numbers, and usually increase in areas often thickly populated by man Over its entire range large areas do not contain the species, but in extensive tracts otherwise barren the deer may be found sparingly in suitable habitats

Deer are hunted in the fall, usually during October and November, when the antlers of the buck have attained their maximum development The finest specimens are obtained in

the Northeast, those of the Southern swamps and Southwestern United States being considerably smaller At this season the bucks are wary and the mature animals may remain effectively hidden in swamps or dense thickets during the hunting season In the Northeast, deer are killed with rifles except in the more densely populated areas, the most effective manner being the drive In this method several hunters station themselves at places where the deer might be expected to pass and wait quietly while others, some distance removed, commence driving the deer ahead of them The latter are armed and frequently have opportunity to shoot at the startled animal as it leaps noisily from its bed or more often skulks stealthily away Still hunting is conducted when a light snow clothes the woods and reveals the tracks The hunter selects tracks of a buck and quietly follows these until the deer is surprised or its tracks indicate from the increased pace that the animal has become alarmed He hurries after the quarry and if quiet and reasonably fortunate secures a shot at the deer Deer are tenacious creatures and will often travel several miles after being struck in a vital spot Many escape to die in the woods where their carcasses provide many a feast for the foxes, bobcats, and shrews through the long winter months A big buck will dress 180 to 200 pounds The weight of deer and, for that matter, of all game is usually overestimated If the gutted carcass is weighed the hunter can estimate the live weight by recalling that the viscera equal about one fifth the weight of the live animal, while the heart liver, and lungs weigh about one fifth as much as the viscera

In the swamps, forests, and delta country of Southeastern United States and the Gulf states, deer are hunted with dogs and hunters usually employ shotguns After taking what is considered a likely place, usually near a stream, lake, or other body of water, the hunter waits until the dogs start a deer Usually the animals make for water to travel in the shallows and thus confuse the hounds or take boldly to the deeper water for deer are adept swimmers Occasionally the hunters

employ horses in the chase, but this method has lost much of the popularity it once enjoyed

Illegal methods consist in establishing salt licks to attract deer, where they are shot in the evening as they come to the lure Jacking, while unlawful, accounts for many deer The hunting party, in a canoe, crowds the shore line of a Northern lake, casting the beam from a strong light along the water s edge, until the eyes of a deer are shined, when the animal is shot Lately this method of butchering has been extended to the highways which penetrate good deer country, and un scrupulous individuals shoot deer from cars as the animals are temporarily blinded by the glare from the powerful headlights

Mule Deer Most important of Western big game, and a joy to the national park tourist, the mule deer (*Odocoileus hemo nus*) has a wide distribution, extending in the north from Manitoba and British Columbia into Mexico This prong tined deer, unlike the eastern white tail, has a wide choice of habitat and its various races are found from the cactus studded plains to the stunted timber of Western mountains

The black tailed deer somewhat smaller than the mule deer is distinguished by its black tail and smaller antlers These little deer range from southeastern Alaska to California, inhabiting the Cascade Range and Sierra Nevadas westward to the Pacific

The huge ears and characteristic bounding gait at once dis tinguish this species from its eastern cousin Furthermore, its habits differ markedly from the white tail, for it moves about with the seasons, the migratory nature being dependent on a readily available source of food The mule deer s gait, unlike that of the white tail, appears awkward, it runs with a characteristic bounding gait, leaping and landing on all fours Undoubtedly this is an adaptation to the rugged country which it inhabits Another characteristic of the mule or black tailed deer is the lack of a flashing tail as it runs off This ap pendage is not carried aloft as it runs, the deer allowing it to hang

The mule deer is the big game of our Western states Every fall thousands of bunters comb the Western mountains the fact that many are successful is attested by the reports of California game officials, who list an average of 23,000 deer killed over the past recent seasons Few big game animals furnish sport to more individuals than the mule deer Ac claimed by many as the finest of all game species, others label it a stupid, slow witted, and slow gaited species which can be killed by the veriest tyro

The Kaibab Plateau of northern Arizona, long famous as an Indian hunting ground in early days, has for many years supported great numbers of mule deer With vigorous predator control and much of the area invaded by domestic stock, the available browse has been seriously depleted by deer, so that these animals have faced a real crisis for some years Fortunately the Forest Service, in close cooperation with Arizona Game officials, has made it possible for sportsmen to take a sizable number of deer and at the same time insures that thousands of tourists to the Kaibab will see deer in their native wild state

6-foot spread, and the great heads of Alaska are generally considered a rare prize of the hunt

The moose is a denizen of Northern forests, venturing nearly to the limit of tree growth In spite of its tremendous size, it can make itself almost invisible in stunted willow growth and other sparse low growing brush In the spring the cows bear their single or twin calves, which grow remarkably fast The moose haunt the waterways during the summer, feeding on water lilies and other succulent aquatics, sometimes wholly submerging their immense bodies beneath the surface As winter approaches and deep snow makes passage difficult, the moose form extensive yards, where trails lead to a suitable food supply of twigs and bark In the Far North and Western America they are said not to yard, feeding not on the bark of trees but rather on the succulent willow sprouts which stand above the shallow snow In spite of its huge bulk, the moose is one of the wariest of big game and may exist for years in areas where its presence has heretofore been little suspected In the national parks of the Western states it is not unusual to see these big animals, and even in the East one may sight a bull moose close to civilization The writer will never forget a red letter day when he sighted a huge bull just outside the city of Moncton, New Brunswick The massive antlers were in the velvet and gave an unusually patriarchal appearance to the splendid animal

Moose are hunted in September and October, at the time when the bulls have matured their massive antlers and are searching a mate The hunter, concealed in his canoe or swamp, calls them with a bark horn, through which be attempts to simulate the voice of the cow moose In British Columbia, a hunter may often attract a bull during the fall by pounding on the trees with a club or rattling willows and other shrubs with a bone The insatiate curiosity of the bulls at this season often lures them to the hunter, although their acute hearing may save them if the hunter does not exercise great caution

Caribou Throughout most of arctic America the Barren Ground caribou (*Rangifer arcticus*) may be found in great numbers Usually occurring well within the arctic circle these huge roaming herds are a mainstay of the nomadic aborigines, who without this important source of meat and hides would perish miserably Indeed when the great herds fail to appear in their usual migratory routes, it often spells disaster for the Indians and Eskimos Farther south, the larger, heavy antlered woodland caribou (*Rangifer caribou*) and its allies haunt the Northern forests from Newfoundland to the Pacific but are practically gone from the United States Their last stronghold exists in the muskeg swamps of northern Minnesota, where three specimens were reported in 1938 In an effort to reestablish the species in the state, federal agencies have introduced nine additional caribou from Canada

select a nice head The situation is somewhat different when one attempts to add a good head of the woodland caribou to his collection Normally these animals are gregarious, but the herds are small, seldom exceeding a dozen animals A single stag dominates the small herds during the rut, but the finest hulls are found alone and are still hunted during October as one would a deer (Fig 82) Probably the finest heads

Fig 82 —A fine woodland caribou stag that was successfully stalked and shot in British Columbia Old bulls are often solitary in the fall and considerable skill is necessary to get within range (*Courtesy Field and Stream Magazine*)

are secured in British Columbia, where the largest of all caribou (*Caribou osborni*) occur in the Cassiar Mountains

Wapiti The stately wapiti (*Cervus canadensis*) extended over most of Northern United States in colonial days, but probably the range of no big game species has been so reduced It is now confined to 21 states, but in only several of these are its numbers sufficient to justify an open season Wyoming, Montana, Idaho Colorado, Oregon and Washington still support considerable numbers, while the species

may yet be found in scattered parts of western Canada, notably in British Columbia, Saskatchewan, and Manitoba Except in the Olympic Mountains, the American elk is not an animal of the dense forests It appears to favor the forest slopes and open parks of the Rockies Here the animals make regular migrations from the higher slopes to the more hospitable lands below during winter, returning to the upper levels with the melting of spring snows

Elk are more given to polygamy than others of the deer tribe, a bull taking several females and roving about with them during the mating season of early fall As spring approaches, the animals become solitary The does, with their single fawn, join together in loose bands with the approach of autumn

The elk, as others of the deer tribe, is hunted in the fall usually during October or November Its handsome white tipped tines, normally numbering twelve in the mature buck are as prized as those of the moose Hunting usually consists of stalking the animal, this is peculiarly easy, for the wapiti is often without suspicion and, when one individual is shot others in the herd often mill about as though undecided upon which course to take—flee or stand their ground When fully alarmed, however, this grand game will often travel miles over terrain few hunters would care to or be able to follow The stupid senseless slaughter of the past century brought this big deer to the brink of extermination, but in the early part of the present century public opinion became sufficiently aroused and some measure of sanctuary was afforded it To day, with proper protection, the elk is not only increasing but has become a problem in parts of the West, where its numbers have resulted in a shortage of winter food A pressing wildlife problem in the Yellowstone National Park is how to provide food for the ever increasing elk herds In the fall of 1938, Montana hunters bagged 4 770 elk, it being the most important big game animal of the state and in the coast regions of Oregon 1,032 were killed during the same season

Other Western states which permit a limited open season for elk are Colorado, Washington, Wyoming, Idaho, and New Mexico

The large number of elk killed in Montana are killed under rather unusual circumstances and in a manner that can hardly be called sportsmanlike The continued notable increase of the elk in the Yellowstone has long been a problem for while food is sufficient for the herd during the summer months the winter range has been sadly overbrowsed and a drastic reduction in the herd has been necessitated In 1934, those charged with the management of the herd agreed that a reduction of 3,000 head was necessary As the elk leave the park early in the year on their regular migration, they move through a bottle necked pass near Gardiner, Montana This spot is known as the firing line, since it is here that in the past few years the wapiti have been slaughtered by the thousands as they leave the pass On certain days hunting is permitted and more than a thousand elk have been bagged in one hunt This butchery has had the desired effect of reducing the herds to a level where the browse is sufficient to maintain them

Bighorn Sheep The bighorn (*Ovis canadensis*) and its several forms range from the coastal mountains of Alaska and the Yukon south into Mexico These big sheep are at home only in the high rugged spots of the Western mountains The largest sheep are found in the Rockies of Northern United States Farther north the big grayish brown rams are replaced by a smaller, almost white sheep (*Ovis dalli*) with less massive horns but the Dall sheep is prized above all other bighorns

In the rugged fastnesses of the Rockies these splendid game animals are singularly sure-footed, and only unusual stalking ability on the hunter s part will permit of a successful shot In its wilderness haunts, there is scarcely a more spectacular wild animal in North America than this handsome wild sheep Unfortunately their numbers have been sadly reduced by a scab disease, possibly transmitted through domestic sheep

which occasionally invade their mountainous habitat during the summer

Hunting bighorns taxes the hunter's strength and ingenuity The animals are quick to discern danger, and their natural habitat is so rugged that a long climb is often necessary before a specimen may be sighted Even then the sportsman must frequently be content with a 600-yard shot Few bighorns are legally killed in the United States, Wyoming and Idaho alone offering the open seasons The best hunting is obtained in Alaska, British Columbia, and the Northwest Territories and Yukon The sizable non resident hunting license and the expense of procuring guides, transportation and other necessities make this animal a trophy in which only the well to do can indulge

The desert bighorn (*Ovis canadensis nelsoni*) is found in the hot barren canyons and mountain ranges of Arizona, New Mexico, and northern Mexico Smaller than the big Canadian bighorns, they are nevertheless much prized for the splendid horns which are larger in proportion to their body weight than those of any other bighorn The scattered and dwindling bands in the United States have been killed by Indians equipped with repeating rifles and by poachers and prospectors who wait at the water holes, where they have taken a tragic toll In Mexico these grand animals appear not to have fared so badly Although the meat is tender and fine-flavored, Mexicans seem content with the mule deer or white-tail and are seldom willing to endure the long climb and hazardous stalk which the rugged country supporting these sheep necessitates

Prong horned Antelope Once roaming the Western prairies in unnumbered hordes, abundant as the bison, the unique pronghorn shared the same fate and at the close of the past century its millions had dwindled to a few thousand animals Drastic measures were taken to give it the desired protection and those concerned with its perpetuation can rest assured that their fight has been successful Ranchers have done much to conserve the antelope On the huge Pitchfork Ranch of Wyo

ming there were only 15 head in 1902, but through proper management these have now increased to 2 000 animals A recent census by government and state officials places the antelope numbers in the United States at 131,555 The greatest numbers are found in Wyoming, New Mexico, Oregon California, and Nevada In the first three states, a limited season permits the taking of a single buck by the hunter

Pronghorns are hunted from the saddle or, more often stealthily approached by long stalks The insatiable curiosity of the antelope often spells its doom, for it will approach a hunter who concealed in the grass or other low growing vegetation of the prairie effectively entices the unsuspecting beast within gunshot by waving a flag blanket, or hat above the brush This method was unusually effective in earlier days but the pronghorn appears to have acquired wisdom with the passing of years which saw many thousands lured to their death in this manner Today it is scarcely less difficult to secure a good head in Wyoming but here the hunter approaches within long gunshot only after a cautious stalk, the animal frequently being killed at a distance of 300 yards or more Antelope meat is delicious and the rich flavor of tender steaks has resulted in much poaching In spite of this illegal pastime, the species seems well entrenched in many parts of the West and there should be little concern over its future

Bears These large carnivores are found in forested regions over much of North America and are highly prized as game animals In the Northeastern states and Eastern Canada the black bear contributes much in the way of sport to fall hunters while the giant brown bears of Alaska the largest of living terrestrial carnivores are eagerly sought by hunters during the spring and early summer

One species or another of the black bear (*Euarctos*) may be found over most of wooded North America except in localities where civilization has made living for these big carnivores too perilous They are common throughout most of forested Canada and continue to maintain goodly numbers in

the Northeastern states The big Florida species (*E floridanus*) excels all other black bears in size individuals occasionally attaining 600 pounds Probably nowhere are black bears so common as in Alaska where their abundance is sufficient to maintain them easily in spite of no protection

Black bears usually pass the winter in a comatose state The tiny cubs are born at this season and as spring ripens into summer the growing cubs follow the mother about putting on a store of fat in preparation for the lean winter months Beats are omnivorous feeding upon fruits berries small mammals grubs and various insects fish and not infrequently the larger game mammals

In Eastern North America bears are hunted during the fall the greater share falling before the guns of deer hunters Experienced hunters who desire to kill a bear often camp on the trail following the animal for several days at a time until the overtaxed beast is finally exhausted In the southern swamps and piney woods these big fellows are pursued with dogs which bring them to bay often after long difficult runs

Grizzlies and Big Brown Bears The Alaskan and Kenai Peninsula provide some of the best bear hunting to be obtained anywhere in the world The mountains often rise abruptly from the shore line but recede at the heads of numerous bays to form large flats and meadows through which one or more streams flow down to meet the tide Extending inward for a mile or more these meadows are the hunting grounds of the giant brownies (*Ursus gyas and U kenaiensis*) These monstrous creatures largest of all terrestrial carnivores sometimes obtain a weight of 1200 to 1400 pounds and their great tracks measure 14 inches (Fig 83) Motor launches and planes bring hunters into these wild and otherwise inaccessible regions Hunting consists in stalking the bears and a fatal shot is necessary or the bear will reach timber where it is unsafe to follow The long open Alaskan season extends from September 1 to June 20 The best hunting for these Alaskan brown bears is the early spring between May 20 and June 20

FIG 83 —The huge brown bears of Alaska are attracted to the salmon streams during the spawning run of these fish These great "brownies" are the largest terrestrial carnivores in the world They are much prized as game

for at this season the pelts are at their best and bears are easier to locate

Grizzlies are hunted in central Alaska, the coastal regions, and parts of Northwestern Canada Their scarcity in the United States has resulted in restricted seasons or complete protection, but the animals nevertheless appear doomed

Polar Bear The hunting of polar bear (*Thalarctos*) today can hardly be considered sport, and the hunter, provided he is in proper territory for such game, seldom taxes his wits or hunting ability There are places in Alaska today where big bears may be shot from the rail of a ship The writer has been told that the same situation prevails along the North Atlantic coast, where tourist trips during the short arctic summer are becoming increasingly popular

Mountain Goat The white goat (*Oreamnos*) of our Western mountains is a large antelope-like creature about the size of a large domestic billy, white throughout the year Both sexes support slender recurved black horns, which seldom attain a length of more than a foot in the largest male Mountain goats still exist in the wilder parts of Washington, Montana, Oregon, and Idaho, but they reach their greatest abundance in Alaska and British Columbia Here they live among the higher peaks, where snow is a commonplace in the landscape the year round It is fortunate that this queer but interesting game animal has elected the inhospitable regions of North western America, else it long since would have been exterminated It is distressing to learn that the mountain goat population of our national forests has remained stationary during the past 20 years Hunting has been relatively light and no overabundance of predatory animals can account for the failure of these hardy goats to increase

It is certainly not the large horns or the rarity of the beast which intrigues the hunter but the difficulty of securing a prize head which, year after year, brings sportsmen into the Alaskan mountains Goat hunting in Montana is not particularly arduous, the hunter being able to drive into the best game

country and after a few hours hike reach good goat range. To get the finest heads, one must hunt the Alaskan ranges where goat hunting is truly the most difficult sport in America. Outfits must be transported on the back of the hunter through glacier fed rivers, rain, fog, and the early September snows.

Peccary. Formerly ranging into Arkansas, the little peccary or javelina is now restricted in North America to Arizona, New Mexico, and Texas. The javelinas are desert dwellers, although in the Sierra Madres of Sonora and Chihuahua, Mexico, they range from sea level to plateaus and mountains 7,500 feet in elevation. Full grown adults weigh from 50 to 75 pounds. The animals are still hunted, but usually dogs are employed by Mexican peons, who kill the animal with a stout club. The thin, strong, bristle-marked hide is much in demand for pigskin jackets and gloves. So great has the demand become, even though the hides bring only 25 or 50 cents, that the animals have been virtually extirpated over much of their range in the past 5 years. More than 85,000 Mexican hides came into Nogales, Arizona, a few years ago.[3] The writer has eaten javelinas shot in Costa Rica and found the meat quite agreeable, although it requires much cooking and the removal of the large dorsal gland immediately after death.

Mountain Lion. Largest of American cats north of the Rio Grande, the secretive mountain lion or cougar has been extirpated over much of its once extensive range and in the East is now to be found only in the wilder parts of Florida and Louisiana. It still roams the forested portions of many Western states, its range extending from British Columbia and Alberta well into Panama and over much of South America. Mountain lions are as much at home in the burning cactus studded deserts of Arizona as in the thick dark forests of fir and spruce near timber line. Their destruction of livestock has started a relentless war by man which has resulted in driving them into the inaccessible canyons and cliffs where dogs cannot easily follow. Mountain lions, like the black bear, are stealthy

creatures and are seldom seen even by experienced lion hunters who spend their lives in the haunts of these big cats

Lions feed chiefly on deer and as a consequence their haunts often coincide with the habitat of the mule deer and black tail Large bucks are taken as eagerly as does, indeed the lions seem to prefer the larger animals The lion is generally credited with killing one deer a week Not only deer but cattle horses and other livestock are destroyed, and the stock interests of the Southwest are concerned with the menace of the mountain lions Lions traverse regular lanes, the males sometimes circling a beat which covers 100 miles or more They are great wanderers and will usually repopulate an area which has been free of their kind for a short time

Lion hunting is a popular sport Trained dogs, often blood hounds or other large breeds but not infrequently Airedales are employed in the chase The more dogs and the noisier the hunt the sooner the lion trees or comes to bay among the rocks Occasionally the hunter will poke the treed animal, to induce a longer chase and thus give further training to the hounds Usually the hounds are followed by mounted hunters but if the going becomes too rough the cat is followed on foot California employs a trained lion hunter to keep these cats in check Mountain lions are given little or no protection and it is only their secretive behavior that has permitted them to survive in the face of tremendous handicaps

Bobcat The bobcat (*Lynx rufus*) with its allies is distributed over much of North America but is considered legitimate game only by Northeastern hunters Those who hunt the snowshoe hare often surprise this animal which after a spirited chase is brought to bay in a tree The pelt adds to its value and for this reason some hunters notably those of Maine, make a regular practice of hunting this furtive little bob-tailed wildcat

Raccoon Considered chiefly as a fur animal the raccoon furnishes as much sport as any species of similar size It oc

cupies every likely habitat from Canada to the American tropics and is found wherever the watercourses and forests meet Hunting is conducted at night, well trained coon hounds pursuing the raccoon until it is treed The eyes of the animal are then shined by a strong beam of light and it is shot

FIG 84 —The raccoon is an important game animal in eastern United States, more than a million animals being shot each season Raccoons are hunted at night with trained hounds, who tree the animal after a spirited chase The hunter then shines the eyes of the coon and shoots it from its perch high overhead Good raccoon pelts have brought as high as nine dollars in recent years, but the average return to the hunter is less than half this amount (*Courtesy Pennsylvania Game Commission*)

from its perch Good coon dogs are very valuable, hunters often paying $100 or $200 for a well trained hound In years of high fur prices, the take of animals by one hound will often pay for the cost of the dog The raccoon is a wary animal, old experienced individuals resorting to many tricks which may leave the dogs quite baffled Wise old coons sometimes lead the dogs into a stream, where, by climbing on the dog's head,

they often drown their pursuers The felling of long-established den trees when the hard-pressed raccoon takes to these has done much to reduce the numbers of this important fur bearer Raccoons are hunted chiefly in November At this season it is not uncommon to bag an entire family, consisting of the mother and her three or four young, in a single tree Hunters in the United States take about a million raccoons each year

CHAPTER XVII

FUR-BEARING MAMMALS

From the dawn of history man has utilized the skins of animals Centuries before the beginnings of agriculture, when the forerunners of our present civilization led a roaming existence, the furs of animals were used by man as a protection against the elements Probably the oldest industry in the world was the taking of furs for clothing, aborigines the world over have been dependent upon fur animals for ages The early explorers and white invaders of North America pushed into the West for fur It is probable that no one factor was of more consequence in the exploration and early settlement of North America than the beaver The beaver, far more than the buffalo, was in all likelihood the most important factor in the development of the West If one reviews the history of Northern America, he soon learns that not gold, agricultural lands, or timber attracted the hardy adventurers, but rather the claims of the fur trade

Following the World War the revival of the fur trade, particularly the demand for white fox, brought trappers and traders into hitherto little known parts of the arctic mainland, and Anderson[1] credits this exploration with disturbing effects on the wild life and the habits and food supply of the entire indigenous population

Great changes have taken place in the fur trade of North America since early days The advent of the railroad, exten

sion of highways, the invention of the steel trap and its increasing refinements, advance of lumbering, mining, and agricultural settlements have driven many fur bearers from their previous haunts. The increased demand for furs has resulted in a drastic reduction of many species, and some are threatened with imminent extermination. This decline has been of much concern to those charged with the conservation of fur resources. As a consequence a more thorough regulation of these resources has been attempted and an effort is being made to administer these animals so as to insure the permanence of the fur supply on a sustained yield basis. Some species, such as the beaver, cannot maintain themselves in areas under intensive agriculture, but others, as the skunk, red fox, and weasel, seem to thrive wherever man has partly cleared the forests and sown his crops. In the United States fur animals generally appear to have decreased, while in Canada under modern conditions the supply appears to have increased, although certain important species, notably the beaver, have certainly shown a marked decline.

THE FUR TRADE

Prior to the World War, Europe was the center of the fur trade and the great auction sales of London and Leipzig attracted fur merchants the world over. During the war, few importations of furs to these centers were possible and American firms commenced to deal in their own products. Thus the fur trade came to the United States, where it has since remained. To appreciate the extent of the fur trade in the United States, the figures of Ashbrook* may be summarized. Imports of furs and undressed skins during the calendar year 1920 were valued at $82,427,592 as compared with $69,289,909 in 1919 and $32,158,939 in 1918. The value of imports for the calendar year 1920 shows an approximate increase of about 22 per cent. Imports of dressed furs and manufactures of all kinds for the calendar year 1920 aggregated $9,131,348 as compared with $7,472,336 in 1919 and

$2,491,278 in 1918 The increase for the calendar year 1920 amounted to approximately 22 per ceot, ot about the same as for the import of raw furs Exports aod maoufacturers of domestic furs for the calendat year 1920 were valued at $32,886,995 as compared with $23,788,599 io 1919 and $11,374,174 io 1918 The Fur Dressers and Fut Dyers Asso ciatioo dressed, during the year 1918, $35,212,230 28 worth of skins, io 1919, $51,366,253 14 worth, and in 1920, $52,910, 589 43 worth The Board of Trade of the Fur Industry of the United States estimates the annual turnover io the fur business for the year 1918 at $232,748,201 86, for 1919, $342,441,687 60, aod for 1920, on which there was a 10 per cent tevenue tax, amounted to $315,311,214 24

Some have placed the annual catch of fur animals at approximately $78,000,000, the investment in fur farming at $50,000,000, the yeatly income to fur farmers at $9,000,000, the annual receipts of the United States Treasury about $10,000,000 from import duties and excise taxes on furs, iocludiog receipts from the sale of seal, blue fox, and preda tory aoimal pelts, and ao amount oot estimated derived from income taxes on thousands of fur-dealing firms, manufac turers, wholesalers, retailers, aod various enterprises io kin dred lines such as dyers, dressers, chemical dealers, etc

Recent figures on imports of furs and manufacturers thereof were valued at $45,837,000 in 1938, against $86,178,000 in 1937 The greater share of these were raw, or undressed, furs Exports of furs in 1937 totaled $17,873,000 but declioed to $14,131,000 in 1938 Io 1917 the United States exported 1,795,-000 skunk, 3,767,000 opossum, 2,522,000 muskrats, 168,000 mink, aod 2,189 000 other furs The value of these was esti mated at $13,604,000 It is thus obvious that the value of imported furs far exceeds that of the exports Chief among imports are rabbit skins, which often total more than 100, 000,000 in a single year Among other important furs which reach the United States from abroad may be mentioned squirrel, weasel, fitch, mole, and marmot

One hundred years ago the value of furs to the export trade of Canada was greater than that of any other commodity and even though its importance is much less than formerly the aggregate is as large as ever, while the number of persons engaged in the industry is much larger A greater variety of furs is now collected than formerly, even the red squirrel being taken in some numbers to satisfy the increasing demand for furs

The demand for fur is best reflected in the rise in price of this commodity During the latter part of the past century muskrat pelts sold for a few cents skunk seldom brought more than 50 cents, while a prime fox and raccoon hide seldom brought the trapper more than a dollar or two With increased use of fur, largely brought on by the automotive industry, which invited more people into the open during severe weather, fur prices rose while the fur bearers decreased Furs because of their scarcity and resultant expensiveness are limited to a rather small portion of the population the wealthy and leisure class Innis[3] believes that the greatest demand for furs is to be found in areas with populations in which class distinctions have been built up inherently as a part of the social organization or which have greatly increased the production of goods through new processes as in countries recently brought under the sweep of machine industry

FUR BEARING ANIMALS

About 25 important fur bearers occur in North America and trappers find it profitable to take a number of others upon occasion The most important group of fur animals is the carnivores one family alone (*Mustelidae*) contributing a major share of pelts to the world market Rodents are likewise of much value, the muskrat leading all other American fur bearers in the total number taken by trappers and for the value received It is difficult to evaluate the importance of any species to the fur trade for demand varies with the seasons and both color and style dictate in a large measure

the popularity of any fur When prices are low and demand lags, the lower priced, less durable, or coarse furs, such as raccoon, skunk, and wild-cat, are in greater demand than the rare and more costly furs as mink, sable, and silver fox In the following discussion the various fur animals are treated in the relative order of their importance to the fur trade

Muskrat The muskrat has long replaced the beaver as the banner of the fur trade Its wide distribution, great numbers, and ability to maintain itself in the face of exhaustive trapping and the increasing destruction of favorable habitat have made it among the most important to the fur trade Muskrat fur is the basic staple of the trade and acts as a barometer of general business conditions within the trade

Trapped in 47 states, Alaska, and Canada, more than 10 million pelts reach the market each year Louisiana is the greatest producing state, more than 6 000,000 rats having been trapped on the coastal marshes in a single season Maryland produces more than a million pelts for the trade each year Almost the entire crop of muskrat pelts is used in the manufacture of ladies coats

Muskrat pelts are processed into Hudson Seal by shearing to remove the long guard hairs and then dyeing the pelts black The pelts which are thus processed must have a heavy greasy skin with a strong leather that can readily absorb the punishing action of the dyes The best Hudson Seal muskrats are taken in western New York, Ontario, New England and Wisconsin Formerly the skins when used in natural condition were used entire on the coat, but the practice today is to cut the pelt into several pieces, matching together strips from the silvery belly, golden sides, or deep-brown to-black back strip From a low price of 8 to 25 cents between 1890 and 1910, the value of raw pelts increased to an all time high of $4 or more in 1920 Since then the price has fluctuated between 40 cents and $2 In addition to the fur value the carcasses are sold in the markets of Baltimore

Wilmington, and Washington as marsh rabbit, thus bringing an additional income to the trapper, who receives from 15 to 25 cents for the carcasses The flesh is delicious and tastes like the finest flavored wild duck

Foxes The red fox, with its various color phases of cross silver, and black, ranks among the most valuable of all fur bearers The tremendous popularity of silver fox has resulted in an extensive growth of the fur farming industry, and today more foxes are raised for their fur than all other wild animals Good silvers once sold for $125 to $500 but the average value of ranch skins is now $45 The red fox and its allies have a wide distribution over most of North America and are eagerly sought by trappers The sagacity and cunning of the fox are proverbial, yet the writer knows of several individuals who consider it a poor season when their scents and traps fail to take 60 to 100 foxes in a few weeks of fall and early winter trapping Red fox pelts have lost much of their former appeal to the trade with the growing silver fox industry, and the current low price of $4 for a prime large eastern pelt is hardly enough to tempt the professional trapper The best red fox skins come from the interior of Alaska

The white fox (*Alopex*) is the most important fur animal within the arctic circle and is a mainstay of the Indian and Arctic trapper During the winter of 1933–1934, 61,400 white foxes were reported to have been taken with an average value of $17 89 The blue fox, a color phase of the white species, is common in Western Alaska where large numbers are ranched under semi-domestic conditions They command a slightly higher price, but the white fox is often dyed to simulate the coat color of the blue fox

The gray fox (*Urocyon*) occurs throughout temperate United States but appears to reach its greatest abundance in the Southern states although there is substantial evidence to indicate that these animals have been invading the Northern parts of the United States within recent years The fur although coarse, is widely used for trimming ladies cloth

garments, and a few pelts are made into scarfs. Good oorthern pelts bring the trapper about $2. The small kit and swift foxes do oot enter the fur trade extensively and their valne is small.

Foxskins are used almost solely for trimming and scarf purposes. Bachrach[4] states that althongh the total of the fox scarfs sold exceeds the total of the scarfs of all other types of peltries taken together, yet the amount is greatly overshadowed hy the total of fox peltries used for trimming purposes. A large share of the pelts which reach the trade are dyed, varying from pale taus to deep shades of brown and hlack

Minks. The wide distributioo of the mink and its soft lustrous coat make this animal a prime favorite with the trapper and cousumer alike. Mink are found throughout the United States and Caoada wherever conditions are suitahle, and the species has held its own fairly well during a century of intensive trapping Mink usually command a good price even during periods when other furs are low. The mink does especially well in captivity and ranks with the silver fox as the two important fur bearers which have been snccessfully ranched oo a commercial scale. Through selective breeding during the past 5 years, farm-raised mink are mnch darker and snperior in quality to the wild individuals. Native mink from Northern states have brought about $10 a pelt during the past few years, while fur farmers have received $18 to $25 for the pelts of mink raised in captivity. The ease of breeding these animals and the small cost and space necessary to produce them have resulted in a tremendous boom As a resnlt, nearly 40 per cent of American mink pelts which reach the market today are from animals raised in captivity Most mink pelts are made into coats and wraps. The smaller female and young male pelts, which are silkier in texture than the larger skins, are used in coats, while the coarser skins are used for trimmings The finest wild pelts are obtained in Eastern Canada, northern Maine, and the

Adirondacks of New York Such pelts are usually small but are invariably dark, unusually silky and lustrous

Skunk The striped skunk has a wide distribution, is prolific, and is little harassed by civilization Indeed, it appears to prosper best in agricultural lands where trapping

levels (1938) are worth about $1.25 but in periods of business affluence have netted the trapper $3 or $4 and occasionally much more. Many skunk pelts are exported to Europe, where there is normally a good demand. Skunk fur is used primarily for trimming cloth and fur coats but in Europe, where the bulk of the furs are used, scarfs, muffs, and trimming absorb a large share of the pelts. The little spotted skunk or civet (*Spilogale*), a common animal of Southern and Southwestern states, is in no way comparable to its big striped cousins. The pelt, from year to year, seldom averages more than 25 cents, but in spite of this large numbers reach the fur market annually. The pelts are made up into short coats or jackets or used for trimmings.

Skunk farming has never proved profitable. The generally low price for the pelts seldom has paid for the cost of penning and feeding the animals, although much interest was shown in this during the fur boom of 1920, when good pelts were bringing $6. The only satisfactory outlet for such animals today is the pet trade and this is, of course, decidedly limited.

Wolves. Representatives of the wolves (*Canis lycaon*) and coyotes (*Canis latrans*) inhabit all the Western plains and mountains, the Northern forests, and arctic tundras. They have been persecuted for many years and their depredations against livestock have set a price on their head wherever they occur. For this reason, as much as for the desirability of their pelts, huge numbers reach the fur markets of the world. The fur has always been much in vogue, and a coyote pelt from the high Rockies is a desirable and beautiful fur. During recent years prime pelts from these regions have brought $11. Northern wolfskins from Canada averaged nearly $10 during the 1933–1934 season and today are much higher. Wolves and, especially, coyotes seem to hold their own against extensive poisoning campaigns and at present the latter species is rapidly extending its range. Most of the pelts are used in trimming ladies' garments and, to a lesser extent, for scarfs. Many are dyed various shades of gray, brown, and

black The finest wolf furs come from the arctic tundra and the region about Hudson Bay, while the best coyote skins are collected in the high Rockies of Idaho

Raccoon Throughout North America, from Mexico to Southern Canada, wherever suitable forests, streams, and marshes occur, the raccoon will be found Because of its importance as a game and fur animal, more than a million raccoon are taken by hunters and trappers annually The raccoon is most abundant in Eastern United States and the great Mississippi Valley Here, in the forested regions bordering lake and river bottoms, thousands are shot by hunters every fall The fur is coarse but handsome and is widely used for sports wear Well matched raccoon coats for women sold for $225 during the winter of 1938 Raccoon coats are extensively used by college and preparatory school students The finest raccoon pelts are taken in Minnesota, Iowa, Dakota, New York, and New England Skins from Minnesota are unusually large and silky The fur is dense and heavy and the fiber is exceptionally woolly

Beaver Beaver was at one time more important than any other pelt but its use declined during the middle of the past century, when silk hats and hats of nutria succeeded those of beaver in public favor Later fur prices recovered rapidly and once more the beaver was harassed, so at the turn of the century this big rodent had been practically exterminated from most of its range in the Northeast Beaver are prolific and their numbers increase quickly when the animals are protected Most of the pelts which reach the trade are caught in Canada, more than 50,000 being taken in an average year In the United States Minnesota, Michigan, New York Pennsylvania, and Maine produce large numbers of these animals The underfur of beaver is close, of a velvety bluish brown hue, and nearly 1 inch deep The reddish brown over hairs are relatively coarse and usually are plucked out in the manufacture of coats Beaver fur is used extensively in the manufacture of ladies sport coats and, to a lesser extent, for

trimming fur garments and cloth coats The long guard hairs are always removed

Marten The marten ranges widely throughout the forested regions of Canada and extends into New York in the East and far down the Western Rockies and the forested Pacific Coast Its pelt is one of the most prized of furs, but the high price obtained and the relative ease of capture of the animal have resulted in a marked decline in numbers Its eventual extermination was feared, so that a much needed 5 year respite from trapping throughout most of the United States is now affording this animal the desired protection During the 1936–1937 season in Alaska, 16,969 animals brought the trappers an average price of $27 35 In recent London auction sales unusually fine skins have sold for $80 The best pelts are taken in Alaska and Yukon Marten pelts are almost entirely used for scarfs and neckpieces, but a few are used as trimming for high priced coats and wraps

Opossum Perhaps no American fur bearer other than the muskrat has maintained such high numbers in the face of years of exploitation as this marsupial Prolific and adaptable, the opossum likewise has an extensive range in temperate United States Its abundance in the Southern states places it high among American fur animals The opossum appears to be invading the North in recent years and is now looked upon as a common animal in states where a few decades ago it was considered rare Specimens have even been recorded for southern Ontario Large quantities are exported to European markets, where the pelts are dyed to simulate skunk Choice northern skins are made into coats, but the greatest use is as a trimming for inexpensive cloth coats Good skins have seldom brought the trapper more than 30 cents in recent years, but, owing to their abundance and to the ease of capture by night hunting, the volume which reaches the trade is enormous

Lynx and Bobcat The Canada lynx (*Lynx canadensis*) is an important species to the Canadian trapper It is one upon

which the trapper of the boreal forests is dependent, and in years of rabbit failure and a consequent reduction in the lynx population, the Northern trapper is hard put to make a satisfactory season Good pelts bring $20 or slightly more when there is a lively demand for furs The best skins are obtained in Alaska and about Hudson Bay These pelts are dense and soft, and both guard hair and fur fiber are lustrous and longer than from other pelts The fur is used principally in scarfs and coat trimmings

The bobcat (*Lynx rufus* and allies) occurs widely throughout United States and Southern Canada, where every major ecologic region has its own species and subspecies The cat is short haired and much coarser than its more Northern cousin and is used principally for trimmings and sport jackets Many pelts are exported to the markets of Europe and Asia Trappers seldom receive more than $2 for good eastern pelts, but the lynx cat of the fur trade (northern bobcat) brings a better price

Fur Seal The history of the fur seal is one familiar to many About 150 years ago the explorer Gerrasim Pribilof discovered the islands which bear his name and made public his observations on the vast herds of fur seals which he had found After years of wanton butchery, in which a great share of the seals killed for their pelts were not recovered, Russia put a halt to these killings After purchase of Alaska by the United States in 1867, the sealing privilege was leased and at the end of 40 years the herd had been reduced to 132,000 A treaty in 1911 between the United States, Great Britain, Russia, and Japan eliminated pelagic sealing The United States now handles the cropping of young bachelor seals, Great Britain and Japan each receiving 15 per cent of the catch The seals are increasing rapidly and are approaching the 2 million mark The Alaskan fur seal herd increased 8 8 per cent during 1937, according to the Bureau of Fisheries, which show a total of 1,839,110 animals on August 10, 1937 as compared with 1,680,743 for the preceding year This

indicates a continued satisfactory growth trend toward complete restoration of the herd During the past 27 years of recovery 768,792 fur sealskins have been taken from surplus male animals and sold for the account of the government

Fur seals are used in the manufacture of ladies fur coats Bachrach says,

> The term Alaska Seal meant to the women of many generations an article of wear which aside from its excellent qualities carried with it a certain aristocratic feeling of elegance that could be indulged in only when one possessed some of the higher priced and scarcer furs

The hair seals (Phocidae) enter the trade extensively but their value is not great The greatest demand is for the young seals, particularly the young of the harp seal (*Phoca groenlandica*), which have a creamy white woolly coat The white coat is usually dyed a darker shade, while the young of the hooded seals (*Cystophora*), which have a bluish black coat, is used natural Subadult harp seals have a spotted coat All these short-haired seal pelts are used for trimming and to some extent in the manufacture of coats for children and women The best pelts are said to come from the North Atlantic, particularly the coastal waters of Labrador

Weasel Weasels are distributed throughout the greater portion of North America and appear to be as much at home in the lowlands of Florida and Panama as on the arctic tundra In the Southern and Eastern states little specific effort is made to trap these small fur bearers, nevertheless large numbers are taken in traps set for skunk, opossum, and other fur animals In Northern states the trapper makes an effort to take this species and often runs a weasel " line of traps, for even though prices be low, fifty or more skins are often taken Within recent years the price for eastern skins has been low, averaging 25 to 40 cents, but trappers often receive $1 for a good pelt Over much of its Northern range, the weasel loses its brown coat in the fall, this being replaced by a pristine coat of white (Fig 32) For many years it was only

the white pelt which attracted the buyer, but today the brown furs command the better price Those changing from brown to white are known to the trade as graybacks and are worth but a few cents The white coat of the weasel is known as ermine, and it and the brown pelts are used about equally for the making of fur wraps and trimming purposes Ermine capes are associated with great wealth, and for many years its use was prohibited by all except titled families It is said that 50,000 Canadian pelts were used in preparation of wearing apparel for the latest British coronation

Badger This squat coarse haired carnivore is found in most of the Western states and extends into the prairie regions of Western Canada Formerly ignored by the fur trade, the pelts rose in value during the post war period when fine-furred northern pelts commanded an all time high price of $50 Such an incentive led many to trap the badger who had formerly considered its pelt worthless, and the animal was greatly reduced in numbers The finest furs come from the mountainous regions of the Rocky Mountain states, where the fur is dense and silky Badger pelts are used in the trade principally for linings on women s cloth coats Even more important, however, is the use to which badger hair is put in pointing fur In the less desirable grades of fox, or, for that matter, many other long haired pelts which may be dyed to simulate fox, the pelts are pointed with badger The long silvery badger hairs are glued in groups of several on the hide of scarfs which have been dyed black, and the skill with which this is done is most deceptive So prominent has this practice become that salespeople understand the process and are usually not hesitant to explain to any prospective customer that the scarf or collar of a cloth coat has been pointed with badger

Otter The otter is prized in the fur trade for its durable fur It has a wide distribution throughout North America from the Atlantic to the Pacific and occurs within the Arctic Circle and well into tropical America Many otters are taken

in southeastero United Stares and Louisiana, but the bulk of the fur comes from Northern United States and Canada Otter is a man s fur and is extensively exported for collars on men s coats In Asia otter trimmings extend all along the border of outer garments to a depth of several inches, the depth depeoding upon the social srandiog of the family In the Uoited States the fur is used chiefly in the maoufacture of women s sport coats The best furs come from Labrador and the Northeastern states Within recent years a price of $10 to $15 has been considered good for prime large otter, but trappers have received as much as $40 or more duriog boom seasons

The lustrous pelts of sea otters no longer enter the fur trade, for these animals have been so reduced by excessive hunting that they are nearly exterminated

Fisher The fisher, a large arboreal weasel, is a prized fur bearer of the boreal forests Not ranging so far north as its cousin, the marten, this big weasel has been heavily trapped for many years The soft, silky fur is highly priced in the trade and as a consequeoce always commands a good price Our knowledge of the breeding habits of the fisher have only recently been established (page 189) and as a result the animal has long lacked much needed protectioo It has oow been given the much needed full protection throughout most of the Uoited States aod parts of Canada The beautiful characteristics of the fur are broughr out only when it is used as a scarf, consequently few are used for rrimming, aod its scarcity aod high price usually preclude its use in full coats Trappers received $40 for good New York skios in 1936, while the finest silky peltries, from Eastern Canada, commaod an even higher price At one time a single pelt of this relatively rare fur bearer brought the trapper $200

Other American Fur Bearers Among rhe host of other North American mammals which unwillingly contribute their pelts to the fur trade, we might menrioo the bear, wolverine, ringtail cat (*Bassariscus*), rabbir, squirrel, and mole

Bears are little used in the fur industry Incredible as it may seem, a good black bearskin will bring little more than a prime muskrat pelt and often scarcely as much Good pelts of black bear sold for $2 during the 1934–1935 season Black bear pelts are chiefly exported, they are used abroad for the tall plumed hats of certain guard regiments, notably British In this country there is a small demand for trimmings on ladies' coats Grizzly- and polar bear pelts find a limited demand for lap robes and a more marked call for mounted rugs in the homes of the well to-do

Wolverine is virtually extinct in the United States but the species persists in some numbers in Canada Because of its scarcity, it is of little importance economically Good pelts once brought a fair price to the trapper, who is ever eager to capture one, not because of its value, but rather to lessen the damage it occasions on the trap line through its destruction of more valued fur bearers In spite of its handsome texture the pelt is coarse, but the writer recalls trading 20 prime musk rat pelts during the post war period for a tanned wolverine skin The fur really has a beautiful pattern, and it is surprising that more are not used for trimmings It no longer is used as neckpieces as formerly, but instead is used almost entirely as trimming on cloth coats The greatest use of the fur is found in the North, where it is used as trimmings for parkas Unlike most other furs, the wolverine fur does not collect and hold moisture, and this is an insurance against breath freezing and causing undue inconvenience to the wearer Five or six hundred are sold by Canadian trappers, who have received less than $5 for the pelts in recent years

The *ringtail* (*Bassariscus*) or bassarisk is a handsome raccoon like creature of Southwestern United States and Mexico, ranging on the West Coast into Oregon It has never been of much importance in the fur trade, but during the boom days trappers received up to $3 for good pelts Probably a price of 50 cents would be nearer the average through the years The pelts are dyed a dark brown and used under sundry trade

names Unfortunately there is little market for the long and beautifully colored tail The usual method is employed, namely that of working in the cheap furs for trimmings on cloth coats

Rabbits The use of rabbit pelts in various manners, either for felting in the manufacture of men s hats or for the manu facture of coats or scarfs, dyed to imitate more valuable furs has a wide use The rabbit or hare pelt is by far more impor tant in the fur trade than any other peltry Some conception of its importance may be visualized when we realize that between 100 and 200 million pelts are imported into the United States every year There is, unfortunately, little demand for American furs The greater share are imported from Australia Elsewhere in Asia and Europe the supply is mostly absorbed by the home markets In North America the arctic hare (*Lepus arcticus* and subspecies) are used to simulate white fox, but the trade in this product is scanty Arctic hare pelts command little more than 5 to 10 cents each, but in years of abundance more than half a million enter the trade from Canada In addition to this many are used among the residents for blankets and robes

American jack rabbits, like all other rabbit skins, are sold by the pound The price varies from 5 to 10 cents per pound which hardly makes it worth the bother of skinning the animals Cottontails have little or no value, pelts selling for 5 cents per pound, at least ten pelts are necessary to make a pound Moreover, the only outlet appears to be through the hatters trade, and this is insignificant when we consider the huge amount imported annually

Squirrel The pelts of squirrels used in the trade are largely imported from Europe and Asia, where better furred and larger species exist, but lately the red squirrel of Canada has found a ready market In recent years well over a million squirrels have been trapped annually and the prices received have been between 9 and 12 cents According to the census of fur taken in Canada during 1934, the squirrel is listed in

eleventh place in value of wild caught furs Squirrel pelts are used in the fur trade primarily for trimmings of fur and cloth garments, chiefly the latter The imported Asiatic squirrel skins are used in the manufacture of fur coats

Mole Moles are used extensively in the fur trade, but are usually dyed before being made into capes and trimmings for cloth coats Essentially all are imported, the best grades being imported from Great Britain and northern Europe The big western mole of North America (*Scapanus*) lacks everything but size and does not take a dye well Good pelts once hrought 35 cents but are in little or no demand in the fur trade today

Other American Furs In this category we might include the house cat, which always is in demand The writer re ceived $1 each for prime black cat skins in the post war era, but today there is little demand for these Domestic-cat skins are used primarily for trimmings on children s gar ments and inexpensive muffs Sundries (vari-colored cats) are scarcely worth the effort of skinning and may be ranked on the level of individual domestic rabbit pelts

Marmots are used extensively in the trade, hut few Ameri can skins enter the market There is no demand for wood chuck pelts

Jaguar and ocelot pelts are used chiefly for rugs and novel ties Nutria (*Myocastor*) is a very important South and Central American aquatic rodent which has a ranking place in the fur trade Its thin haired dorsal surface has no value, but the dense belly fur, not unlike that of beaver, is used in making ladies coats, being used in natural condition

THE TRAPPING INDUSTRY

For centuries man has pursued wild beasts, both for food and for fur, and the pursuit, while not so pronounced as formerly, continues with little abatement Many individuals are more or less dependent on the returns from the trapping season, while others pursue fur bearing animals as much

for the sport and the desire for an outdoor occupation In the United States, the greatest share of trappers are boys or young men living in the rural districts, who trap during the early winter when farm work is slack and in this manner add to their enjoyment and otherwise meager income In a survey[5] of Northeastern trappers, the writer has observed that by far the greater share of trappers were schoolboys who, while not so experienced as older trappers, yet succeeded, collectively, in taking the larger share of the fur crop Many young men in the rural villages are also accomplished trappers and make a tidy sum from their efforts on the trap line Probably the greater share of farm fur bearers, such as skunk, opossum, weasel, mink, and lesser species, are taken by these boy trappers Most of the raccoon, on the other hand, are taken by hunters who employ well trained hounds, hunting solely at night and as much for the sport as the financial gain they might anticipate Many opossum and skunk are taken in a similar manner, particularly in the lower Mississippi Valley The return to the farm boy trapper will average between $4 and $60 a season, depending on fur prices, abundance of animals, and human competition Another class of trapper, properly classed as a professional, may seek temporary work during the summer months but invariably returns to the trap line in the fall, where he traps the same territory year after year In the marten country of the high Rockies, it is not unusual for the experienced trapper to net $1,500 in a single season The successful coyote trapper of the Southwest usually traps less than a thousand dollars worth of fur, while the Adirondack trapper or one who works the spruce forests of Maine seldom collects more than $500 worth of pelts (Fig 86) Exceptions to this are many, and young lads have made a substantial sum, when fur prices have been high from the proceeds of their muskrat pelts taken within the city limits of New York

In the vast delta country of Louisiana, and to a lesser extent on the salt marshes of Maryland and Delaware, a

system for private control of muskrat land has grown up. Here great areas of swamp are held in large tracts, from ten thousand to several hundred thousand acres. On these large tracts the controlling company erects drying sheds, equips comfortable and permanent cabins for their hired trappers, dredges navigable canals through the marshes, and employs wardens to patrol the marsh to prevent poaching and reduce predators during the summer months. The owner of the land has complete control of the extent and manner of trapping

FIG. 86—A trapper's cabin in the Maine woods.

If the catch seems unduly small at the commencement of the season, the trappers are called out of the marsh, and a season of respite given the muskrat to recover their numbers. Here we find an instance in the United States where individuals are almost solely dependent on the trapping of fur bearers for a livelihood, but such, fortunately, is not met with elsewhere in the Union.

In marked contrast to the situation in the United States, we find that in Northern Canada a large population is directly dependent on their success in taking fur animals North of the settled regions, some 20,000 Indians and Eskimos of a

total population of 60,000 remain permanently on their tribal hunting grounds These aborigines must depend on the fur crop, for agriculture is here impossible and furthermore

KINDS, NUMBERS, TOTAL VALUES AND AVERAGE VALUES OF PELTS OF FUR BEARING ANIMALS TAKEN IN CANADA
Years ended June 30, 1934, and June 30, 1935[7]

Kind	Number of pelts		Total values of pelts		Average values per pelt	
	1933–1934	1934–1935	1933–1934	1934–1935	1933–1934	1934–1935
Badger	3 051	1,225	$ 32,971	$ 9,426	$10 81	$ 7 69
Bear, black and brown	1,416	1,123	1,830	1,845	1 29	1 64
Bear, grizzly	1	10	12	45	12 00	4 50
Bear, white	27	43	405	572	15 00	13 30
Beaver	59,199	50,175	476,391	412,862	8 05	8 23
Coyote, or prairie wolf	28,914	53,018	227,501	359,036	7 87	6 77
Ermine (weasel)	753,916	577,688	445,754	276,502	0 59	0 48
Fisher or pekan	3,171	3,725	169,295	170,064	53 39	45 62
Fitch	2,754	2,510	3,564	2,931	1 29	1 17
Fox, cross	28,833	32,799	687,344	694,174	23 84	21 16
Fox, red	81,513	104,468	648,084	781,709	7 95	7 48
Fox, silver*	103,589	120,465	3,711,390	4,343 823	35 83	36 06
Fox, blue	1,151	1,316	21,219	32,550	18 44	24 73
Fox, white	61,400	68,366	1,098,421	1,043 028	17 89	15 24
Fox, unspecified	273	1,163	1,999	8,508	7 32	7 32
Lynx	16,799	22,014	285,048	511,410	16 97	23 23
Marten or sable	17,660	22,906	201,771	318,463	11 43	13 90
Mink	227,053	183,305	1,822,774	1,540,684	8 02	8 41
Muskrat	2,538,565	1,983 747	1,863,322	1,784 252	0 73	0 90
Otter	8,868	8,927	155,509	152,404	17 54	17 07
Rabbit	466,492	288,641	35,977	18 097	0 08	0 06
Raccoon	26 072	20 101	99,678	69,309	3 82	3 45
Skunk	162,620	131,940	112,253	87,154	0 69	0 66
Squirrel	1,472,920	1,231,290	171,338	109,757	0 12	0 09
Wild cat	1,917	2,218	6,428	7,759	3 35	3 50
Wolf	7,097	12,007	67,173	102,918	9 46	8 57
Wolverine or carcajou	456	655	1,783	3,988	3 91	6 09
Domestic cat	470	565	94	71	0 20	0 13
Totals	6,076,197	4,926,413	$12,349,328	$12,843,341		

* Output of fur farms

their nomadic habits are not fitted for farm life. Because it is felt by Dominion officials that there is a sufficient native population in Canada to trap annually all the furs that the supply can afford, restrictions have been placed on the white trapper. Thus northern Quebec and Ontario are more or less closed to all but native trappers. Saskatchewan requires 5 years residence in the northern section to qualify a white man for a trapping license and Alberta has set aside certain areas for Indians only. Eventually it is anticipated that before many years all northern trapping will be the privilege of Indians and Eskimos.[6]

In the peak year of 1929, when fur prices were high and a lively demand for furs of all kinds existed, the return to the trapper, it has been estimated, was $60,000,000. The returns to trappers of several states exceeded $2,500,000 each. As prices declined, the income from the sale of pelts dropped drastically and, even though as many furs were taken during the early years of the depression, the income to trappers could scarcely have exceeded $25,000,000 in any one year. People who are unaquainted with the fur trade and the trapping industry can scarcely appreciate the importance of this return. Not large in the sense of many major industries, it nevertheless represents a unique situation, in that the return is spread over a great area to a small wage earning group at a time when living conditions are severe and money at a premium. In brief, this fur crop means life to the nomadic Eskimo or Indian of the arctic, who has no income other than that from hunting and trapping. A small amount of flour and tea through the sale of a fox pelt may keep an Indian family from starvation. In the North, wherever a poor settler is barely able to raise a crop on submarginal land, the sale of fur may budget the family through an otherwise disastrous year. Farmers and ranchers throughout the United States might not otherwise prosper if it were not for the few fur animals for which they find a ready market. Within recent years men who could not

otherwise find employment have left relief rolls to trap fur animals, many with considerable success

Not the trapper alone, but the many fur buyers scattered over the country profit from this important harvest Nearly every small town has one or more individuals who buy fur The buyer may be a merchant, traveling grocer, or farmer (Fig 87), but all receive a small income for their share in

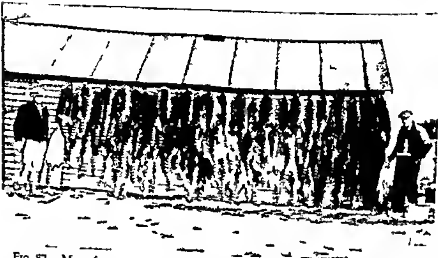


Fig 87 —Many farmers buy fur locally during the slack season of late fall and winter These men have purchased $400 worth of raccoon pelts during two weeks of November and will later sell them for a substantial profit The pelt on the stretcher to the left is turned flesh side out and shows the appearance of a good prime hide The one on the extreme right is unprime

collecting and grading the furs for the large markets Most of these buyers realize a 5 or 10 per cent return for their invest ment, and, where the quantity of fur handled is large, it may return a sizable profit to the buyer Dearborn[8] cites many examples where country fur buyers have made handsome profits from the resale of furs bought directly from trappers Local Michigan dealers handle from $1,000 to $20,000 a year in furs while in Missouri the average small dealer handles more than 1,000 pelts in a season New York buyers, who for the most part conduct such trading as a side line to farm

AVERAGE PRICES RECEIVED FOR PRIME NO 1 FURS OVER TWENTY-YEAR PERIOD

	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938
Muskrat																				
Northern	$4 00	$1 25	$1 75	$1 40	$2 00	$1 50	$1 75	$2 00	$2 00	$2 75	$1 50	$1 00	$0 70	$0 40	$0 50	$1 00	$1 60	$1 70	$1 60	$1 25
Southern	2 75	0 40	0 75	0 60	0 80	0 65	1 35	1 10	1 20	1 40	0 60	0 50	0 40	0 30	0 30	0 40	0 75	0 75	0 60	0 65
Skunk																				
Northern	6 00	2 00	5 00	2 00	5 75	2 50	2 75	2 50	2 75	3 00	2 00	1 75	1 50	1 00	0 90	1 00	1 40	1 75	1 50	1 50
Southern	4 00	1 00	1 00	1 00	2 00	1 10	2 00	1 00	1 50	1 50	1 00	0 90	0 60	0 50	0 40	0 40	0 50	1 00	0 75	0 60
Raccoon																				
Northern	9 00	5 50	5 00	5 00	6 00	5 00	6 00	9 50	7 00	8 00	6 00	5 00	4 00	3 00	3 50	4 00	4 25	6 00	5 00	5 50
Southern	6 00	1 25	2 00	2 25	5 00	1 50	4 00	5 00	4 50	4 00	3 75	3 25	2 00	1 00	1 00	1 00	1 25	3 50	2 00	1 00
Mink																				
Northern	12 00	6 00	8 00	6 00	9 00	8 50	10 00	12 00	12 00	16 00	13 00	9 00	5 00	3 50	4 00	7 00	10 00	9 00	10 00	10 00
Southern	5 00	2 50	5 50	5 00	5 00	3 00	4 50	7 50	6 00	7 00	5 00	3 50	2 50	1 50	2 50	3 00	3 00	5 50	4 50	4 00
Red fox																				
Northern	20 00	12 00	15 00	10 00	11 00	11 00	14 50	12 00	17 00	22 00	17 00	11 00	5 00	5 00	5 00	6 50	7 00	5 00	5 00	4 00
Southern	6 00	6 00	6 00	5 50	5 00	5 00	7 50	6 00	7 00	8 00	7 00	4 75	3 00	3 00	3 00	3 00	3 00	3 00	2 50	2 00
Gray fox																				
Northern	4 00	1 50	2 00	1 00	1 75	2 00	2 75	2 50	2 50	2 75	3 50	2 75	1 25	1 00	2 50	2 00	2 00	1 50	1 50	2 00
Southern	1 50	0 75	1 00	0 75	1 25	1 25	1 50	1 75	1 25	1 50	2 00	1 50	1 00	0 60	1 50	1 50	1 25	1 00	0 50	1 00
Opossum																				
Northern	2 00	0 50	0 75	0 75	0 75	1 00	1 25	1 20	1 00	1 25	1 00	0 60	0 45	0 40	0 50	0 40	0 50	0 50	0 40	0 30
Southern	1 00	0 30	0 50	0 30	0 50	0 40	0 75	1 00	0 80	0 75	0 50	0 50	0 30	0 20	0 25	0 30	0 30	0 20	0 20	0 20
Coyote	12 00	1 25	7 50	7 00	7 00	8 00	8 00	7 00	10 00	12 00	6 50	4 50	3 50	3 00	3 00	3 50	4 00	6 00	5 00	5 00
Beaver																				
Northern	18 00	12 00	25 00	20 00	18 00	20 00	22 00	20 00	25 00	25 [illegible]	15 00	15 00	11 00	7 50	8 00	10 00	12 00	10 00	8 00	10 00
Southern	14 00	6 00	15 00	12 50	10 50	10 00	11 00	11 00	17 00	18 00	9 00	8 00	7 00	5 00	5 00	6 00	6 00	7 00	4 00	6 00
Otter																				
Northern	25 00	10 00	20 00	25 00	22 00	25 00	25 00	20 00	20 00	25 [illegible]	22 00	17 00	12 50	6 00	9 00	13 00	13 00	12 00	12 00	14 00
Southern	7 50	5 00	6 00	7 00	7 00	12 00	10 00	12 00	12 00	14 00	15 00	11 00	6 50	4 00	4 50	8 00	8 00	5 50	3 50	5 00
Bobcat																				
Northwestern	4 50	1 50	4 00	2 00	5 00	2 50	6 00	5 00	6 00	6 [illegible]	5 00	4 00	2 50	1 25	0 75	1 25	3 00	2 00	2 00	1 50
Southwestern	1 75	0 50	0 75	0 50	1 00	0 50	1 50	1 50	1 50	1 75	1 25	1 25	0 50	0 40	0 30	0 60	0 50	0 75	0 75	0 50
Weasel																				
White	2 00	0 50	1 00	1 25	1 00	1 50	2 00	2 00	2 00	2 [illegible]	1 50	1 00	0 90	0 40	0 50	0 50	0 60	1 00	0 70	0 30
Brown	0 20	0 05	0 20	0 05	0 50	1 00	1 00	1 75	1 50	1 75	1 50	0 90	0 75	0 40	0 60	0 70	0 75	0 90	0 70	0 45

duties, may buy $30,000 worth of furs from trappers in a single year, but more often the value runs about $2,000 to $5,000 It is thus apparent that individuals in rural communities in addition to the trapper profit directly from the fur trade

FUR FARMING

Raising animals under domestication for their fur and hides can scarcely be considered new, for sheep, goats, and dogs have been bred for this purpose for centuries However, the raising of fur animals for their pelts is a relatively new industry Abortive attempts to keep silver fox pups and other valuable fur bearers, dug from their den while small and penned until the fur became prime, were carried on by Indians who, during the days of silver fox scarcity, might realize $1,000 from the sale of a single pelt The real beginnings of fur farming go back less than half a century, when Charles Dalton and Robert Oulton, both of Prince Edward Island, began experimenting with silver foxes Some they bought and others were taken in traps By breeding cross foxes with silver black individuals, these experimenters finally obtained a number of fine black and silver pups Soon they were producing enough stock to place on the market and in 1910 sent to the London sales 25 unusually fine pelts So much finer were these than any previous pelts to reach the market, that frantic bidders paid unheard of prices The finest pelt sold for $2,624, while the average price of the lot was $1,386 Immediately the word got out that these pelts had been produced in captivity, a great yearning for such easy profits gripped many and as a result the inevitable boom started Breeding stock was scarce and unscrupulous charlatans, knowing nothing about fox ranching and caring even less, started a great ballyhoo By 1913 a pair of pups would bring $13 000 and paired breeders that had proved their worth were sold for $35,000 The World War put an end to such unsavory business, but shortly after its close individuals were again selling stock in fur ranches and incredulous investors were paying fancy prices for animals they had never seen Such

promotional schemes finally came into disfavor with the public and by 1926 such unhealthy speculation had largely abated The annual production of silver fox pelts from ranch raised animals had reached 25 000 and an average lot of skins brought $125 apiece There was some rightful concern about overproduction Increasing costs of labor and feed had put many fur breeders in bankruptcy, and the larger producers were alarmed lest the increasing output from their farms would bring a decline in prices to a point where it would prove no longer profitable to raise the animals

During the early days of fox ranching attempts were made to raise other animals for a profit The cost of maintaining housing, and feeding those species of which the pelts do not command a high price has rendered the venture altogether unsuccessful Efforts to raise skunk raccoon, muskrat, red fox, and mink were made but only the raising of the last has proved commercially feasible During the halcyon post war period, when fur prices skyrocketed and black-skunk pelts brought the trapper $6, it was inevitable that numerous attempts to raise these animals should be made If such prices could have been maintained it would have proved feasible, but the cost of raising a skunk is greater than that of raising a mink and the value of the pelt is much less than that of a mink

With the expansion in Canada of fox farming the chief source of income for a number of years was the sale of live animals for breeding purposes, while the production of pelts was a minor or incidental feature Thus in 1925 the value of live silver foxes sold in Canada was $2 755 000 and that of silver fox pelts was only $736 000 As the number of foxes on fur farms increased, the ranchers had to readjust their economy to declining values for both live animals and pelts A decade later the value of live silver foxes sold had declined to $562 480, while that of silver fox pelts sold was $3 690 431 and for all fur farms in the Dominion the sale of pelts represented 88 per cent of the total revenue

Some conception of the importance to the fur industry of ranch raised animals may be obtained from the knowledge that 40 per cent of the fur production in Canada for 1936–1937 came from fur farms. Canada has more than 8,000 fur farms and the United States has more than 20,000 people engaged wholly or part of the time in the raising of foxes and mink. Ten years ago the number of pelts sold by fur farmers on ranches was insignificant. In 1938 about 300,000 silver fox pelts and 200,000 mink pelts were sold from the fur farms of North America. These skins represented nearly 20 per cent of the value of all raw furs sold in the United States, or roughly $13,000,000.

North America leads in the production of ranch raised silver foxes. Half of the farm foxes in the United States come from Wisconsin, Minnesota, and Michigan. In Canada, Prince Edward Island was the birthplace of the fur farming industry and in 1936 there were 730 fur farms, all but one of which were engaged in the raising of silver foxes. Quebec and Ontario are now the leading producers of ranch raised fur animals. Norway and Sweden produce large numbers of silver foxes.

The greater share of fur animals bred in captivity are produced by the small breeders, whose several dozen mink or foxes raised as a side line to the usual agricultural pursuits contribute about 70 per cent of the total production. Nevertheless, there are many notable exceptions.

The largest fur farm in the world is located at Hamburg, Wisconsin, where the Fromm Fur Farm produces 12,000 or more silver fox pelts a year. Nearly $18,000,000 worth of silver fox skins have been sold from this one farm, which covers more than 12,000 acres. A smaller farm of 1,100 acres at Thiensville, Wisconsin, cares for the breeders. More than 400 people are employed the year round and the value of the properties is placed at $10,000,000.

These silver foxes eat a staggering amount, in a single year the Fromm foxes consume 9,000 to 10,000 cattle and some worn-out but healthy horses, more than a thousand

tons of bread and a similar amount of cereal, 600,000 pounds of liver, 800,000 pounds of carrots, aod 100 tons of lettuce in addition to a carload of cod liver oil and quantities of canned vegetables or fresh vegetables when these are avail able A trained staff of nutrition experts, veterioarians, aod other experts are oo haod to admioister to the oeeds of this big ranch In the early fall, the foxes which are to be pelted are temoved by motor 200 miles north to Hamburg to be

Fig 88 —A scene on the Fromm Fur Farm in W scons n the largest of its kind in the world Dur ng the fall these s l er foxes are perm tted to roam through th s fenced woods where they appear to prime better and acquire a more lustrous coat than do caged animals (*Photograph by Fromm Bros*)

turned loose in woods of 40 to 80 acres each where they acquire the requisite prime coat in the early winter (Fig 88) Thus the wear frequently seen on caged animals is avoided The marketiog is done through auctions held on the Fromm farm, where fox and miok pelts of smaller breeders from all parts of the United States are sent to be sold

The world s largest mink farm is located at Fort William Ontario, where one-quarter of Canada s 44 000 captive mink are housed Here 7,000 animals are being pelted annually

although the farm has been operated only since 1933 The value of the pelts produced in 1938 was estimated at $1,000,000 Twenty five men are employed throughout the year on this mammoth ranch, where a million pounds of food is required to keep the colony in good health

These are the large farms For every ranch which has a hundred animals, there are countless farms which provide their owners with only a few dozen pelts each season Nevertheless these small establishments provide the fur trade with the greater share of ranch raised animals, and their numbers increase every year

Breeding Fur Animals Most species on fur farms are kept closely confined, where they may be under rhe close scrutiny and care of the owner at all times

Blue foxes have heen raised on islands off coastal Alaska where they are permitted to roam free From the progeny of these animals other islands have been stocked The animals are fed fish, which are readily obtainable in sufficient numbers, or hair seal and sharks are utilized Blue foxes have been raised in captivity in a manner similar to those used in the production of silver foxes but the free island life seems to produce a finer fur Long Island, near Kodiak, Alaska, has likewise been stocked with raccoon in recent years, and these animals have now increased ro a point where they have real commercial value

Efforts have been made to raise marten and fisher on a commercial scale, but it has only been within recent years that the requisite breeding knowledge of these animals has been obtained and with such data the breeding of these species seems to merit further effort Neither animal is yet raised in quantities sufficient to warrant pelting any surplus (Fig 89)

Muskrat farming is conducted extensively, but few musk rats are raised in confinement W A Gibbs has experimented considerably at Dorchesrer County, Delaware with the production of captive muskrats His efforts have not met with

much success, although several New York breeders have solved the problem of the commercial production of muskrats by confining them in pens One breeder has developed management technique to a point where production approximates the breeding potential of the species A single pair of year old muskrats have produced 22 young in a season The animals are kept in wire pens 3 by 3 by 4½ feet (wide) connected

FIG 89 —These young martens were raised in captivity a feat long thought impossible The marten has a long breeding season mating in midsummer and bearing young the following April Pelts are much in demand and command a good price (*Photograph by K P Batten*)

with sheet iron closed pens The captives are fed lawn clippings, carrots and beet tops, cabbage, cull apples, and corn stalks A constant supply of whole-grain corn is kept before the animals to keep the sharp incisors in proper condition Kits born in September may be sold as full grown pelts by late January It now remains only for large scale production to reduce housing and labor costs to a point where a moderate profit can be realized from the sale of prime pelts

Most of the muskrat farms are located on extensive marshes, where the land is either fenced or constantly patrolled to

prevent poaching One corporation in Louisiana controls 140,000 acres, while smaller tracts are maintained in Michigan, Delaware, and New York Extensive ditching increases the available water and encourages muskrats to breed rapidly One marsh of 950 acres produced 4,205 muskrats in a single season where formerly the same area had never yielded more than 700 pelts

Mink are kept in small cages having an open run with a suitable nest box under cover Usually these cages are placed under long covered alleys Mink are fed a mixture consisting of meat or fish, cereals, eggs, vegetables, milk, minerals, etc The food is always thoroughly mixed and ground up, which prevents the animals from storing the mixture in the nest box The mixture usually consists of 60 per cent meat (beef, beef liver and hearts, horse meat, pig liver and hearts, or fresh fish), cereals, of which fox bread or commercial cereal is most popular, ground green bone or bone flour, tomatoes, lettuce, spinach, carrots, and enough milk to make the mixture damp Adult mink are fed once or twice a day and will consume 3 to 5 ounces daily Large producers can feed their animals at a cost of 1 cent a day Inasmuch as most animals are pelted when they are 7 to 8 months old and good pelts have averaged more than $20 during the past two years, it is obvious that a good profit may be realized from the animals if loss through disease can be minimized Mink are bred during late February and March, producing an average of four young on the fur farms Until recently the greatest profit has been derived from the sale of breeding stock, good animals bringing $75 to $100 apiece The industry, to survive ultimately, must exist on the basis of pelt production alone, and such a situation appears to prevail at the present time

CHAPTER XVIII

PREDATORY MAMMALS

During the past few years, militant efforts have been made to conserve our vanishing wild life. Research by competent field naturalists on many fronts has provided us with new concepts of nature These studies, beside providing desirable information on methods which may conserve our native fauna, have likewise dispelled many popular notions that formerly existed Unfortunately, the laity has not been educated to the value of predatory species, and many, if not most, of these are still considered as "vermin." Predatory mammals are ruthlessly destroyed in many states on the assumption that their decrease will witness a revival of game populations Alluring bounties, encouragement of vermin campaigns, and the indiscriminate slaughter of predators has continued for years, yet there is little evidence that such wanton killings have increased our game species.

Many now believe this destruction of predatory animals to be unwise, others are commencing to question the wisdom of predator campaigns. Nevertheless, there still exists a large minority charged with the administration of our wild life who believe a predatory species has no place in the scheme of wildlife restoration This group generally loses sight of the fact that since time began flesh eaters have preyed upon plant eaters to the mutual benefit of both races. Predatory species are a check to the undue increase of herbivores; with-

out them the herbivores must increase until disease reduces their ranks or their food supply is exhausted, when they speedily starve

Olson[1] reflects a changing attitude toward the predator when he writes

> The extermination of predators is no longer a strictly economic problem, for other factors have entered in, factors of scientific, recreational and esthetic value With the fast growing appreciation of the true meaning of wilderness, we are beginning to question the idea of the total elimination of predators, realizing that, after all, lions, wolves and coyotes may be an exceedingly vital part of a primitive community, a part which once removed would disturb the delicate ecological adjustment of dependent types and take from a country a charm and uniqueness which is irreplaceable To go into a region where the large carnivores are gone, to see hoofed game with its natural alertness lacking to know above all that the primitive population has been tampered with, is like travelling through a cultivated estate Wilderness in all its forms is what the true observer wants to see and with this realization dawns a new appreciation of carnivores and the rôle they play

Some may argue that the disturbance of the environment by man has changed natural conditions to such an extent that predator control must be practiced There are many instances which show such a thesis to be untenable One will suffice In 1906 the Grand Canyon National Game Preserve, covering almost the entire Kaibab Plateau of northern Arizona, was established All killing of deer was prohibited and government hunters were employed to destroy predatory mammals, particularly the mountain lion and coyote The removal of these predators resulted in a tremendous increase in the deer herd So abundant did they become that a food shortage became imminent This precarious condition was aggravated by thousands of livestock which shared the food By 1920 the range was taxed beyond the limit of its carrying capacity Eventually many deer died from starvation Predators are now controlled so that their influencing factor will reach a balance [2]

Paradoxical as it may seem, campaigns against predatory mammals may have the undesired effect of causing an increase in predation, which might in turn, through man's interference, have a disastrous effect on prey species. Wolf packs during the winter frequently kill more deer and other game than can immediately be consumed. The carcasses are left where they are struck down, but wolves invariably return to these kills, thus finding a ready meal when hunting proves unsuccessful. This storage habit is said to be instinctive in northern wolves. In fact, it is well known to trappers that a frozen carcass, perhaps several weeks old, will be revisited by wolves and traps set about these caches often take an animal or two. With increasing use of poison and trap, wolves are becoming more wary and give these old kills a wide berth. As a result, an abnormal situation prevails, in which more prey must be taken to satisfy the pack. Under conditions of equal sanctuary for both predator and prey such a deplorable condition would not exist.

In commenting on the similarity of feeding habits between Russian and Michigan foxes, weasels, and badgers, McAtee cautions against overzealous control of predators. He says:[3]

> Only a few of the species can justly be classed as chiefly injurious and the others under ordinary circumstances do more good than harm. This is inevitable from the very nature of predator-prey relationships. The flesh eaters must subsist either directly or indirectly upon the vegetation consumers. Man's crops are chiefly vegetable, hence these vegetation consumers include most of the creatures regarded as pests. Any predator upon them is in some degree man's ally. When animal crops are involved, predators may become injurious, but this is a special case. It should be recognized that in Nature nearly all predacious creatures tend to be beneficial from man's point of view, and control plans and practices should be based on this understanding.

COMPLEXITY OF PREDATION

Few people, unless they are trained observers, have the power to observe the countless interdependencies, however

simple these may be, which exist all about us No species of animal or plant is self sufficient Darwin was one of the earlier naturalists to make clear the intricate and often baffling interrelationships of nature, which are often termed the Web of Life His classic example showing the relationships between cats and clover is known to all biologists It is not difficult to enumerate many similar examples A few instances showing the relationships which exist between predatory mammals and game species will be given

The apparently insignificant mice of arctic countries have an importance quite beyond their small size and obscure ways Like the hares, they increase periodically and then suddenly disappear Cabot[1] has recorded the importance of these little rodents in Labrador In 1903 mice were not noticeably abundant, although caribou gyrfalcons, hawks, and foxes were fairly plentiful The following year mice were distinctly abundant and, with this increase, hawks became more numerous Foxes were noticeably shy, refusing to take bait placed by the trappers Ptarmigan were fairly numerous Cabot shot wolverine which were full of mice Hardly any caribou could be seen, although the silent wolves roamed along the river banks feeding upon the mouse horde

howl at night, caribou were moving into regions not visited in several years Cabot says

The bearing of the mouse situation on the human interests of the region is easy to see It affected all the game, food game and fur The abundance of mice tended to build up the ptarmigan, which are of vital importance in the winter living of the Indians, through the whole forested area of the Gulf Likewise it built up the caribou herd by providing easier game than they for the wolves

The departure of the mice did the reverse, reducing the deer [caribou] and ptarmigan, but it may have brought the deer migration as suggested, giving at any rate an easy year to the hard pressed Indians of the George At last they had good food and new clothes and lodges, in all of which necessaries they had gone very low They killed too many deer at Mistinipi, still very many passed south the next year There have been deer in the country ever since, with not many mice

All in all it is hard to imagine any other natural change which would have affected the fortune sometimes the fate, of all the other creatures of the peninsula, from man to fish, as did the coming and going of the mice from 1903 to 1906 Only fire could have done the like Nor were the shore people by any means untouched All their land game came and went, was plenty or wanting, shy or easily taken, according to the supply of mice London and St Petersburg, easily, were affected through their great fur trade

sufficient Finally, through force of circumstance, the turtles added ducklings to their fare until the few ducks that refused to leave the marsh paid the penalty of their persistence by rarely bringing to maturity more than one or two young At last there came about a depreciation in the value of skunk pelts, with a corresponding loss of interest on the part of the trapper, so that the progeny of the surviving skunks congre gated at the old beach aod devoured the eggs of the turtles

good years the grouse, as they do in America, died off from disease because they had become so populous At the same time, the Norwegians had a great drive to wipe out birds and animals of prey, eagles, foxes, martens, and other fur animals As the birds and predatory mammals have become scarcer, it has been noticed that the epidemics among willow grouse have become increasingly worse Instead of more and better willow grouse populations having been produced by supposed protection through widespread destruction of predators, the stock of these birds has become progressively more decreased

It was suggested that the reason for this greater mortality was this when a grouse became sick with coccidiosis, it weakened and flew less readily and was thus easier to catch As a result, in the old days the predators used to catch the sick birds more readily than the healthy birds and so prevented disease from becoming too severe, except after the birds had become very abundant

When one engages on a study of any wild species, he soon finds his attention drawn to other species in similar habitats After a few years evidence accumulates which discredits preconceived ideas in respect to such important factors as interrelations It is common knowledge that the red fox will not pass up a grouse dinner when opportunity offers, even though his usual bill of fare is made up primarily of small rodents, fruits, and berries Investigators who studied the grouse in Minnesota found that chipmunks were responsible for some mortality This little striped ground squirrel, so abundant in the Northern woods, was observed to roll grouse eggs from the nest, play with the eggs, and then hide them, usually without breaking the shell One nest with twelve eggs was discovered, but on the following day the eggs were all gone Search revealed all the eggs hidden away by the chipmunk

The red fox, fond as he is of grouse, evidently finds it much easier to capture and dine on chipmunks Not only are the stripers far more numerous, but they cannot take to the air

as a grouse when pursued That foxes can and do destroy chipmunks is amply demonstrated by finding their remains in the stomachs and droppings of these animals If we study the simple food chain below, we are at once made aware of the importance of considering these interrelationships The chipmunk is a predator of the grouse, the fox is a predator of both grouse and chipmunks But chipmunks are far more abundant than foxes, perhaps 200 times as numerous in a given area Inasmuch as the fox destroys far more of these ground squirrels than grouse, it might well be argued that the fox is not only entitled to a few grouse but, further, is an actual asset to this bird by its destruction of a far more potentially dangerous predator of the grouse

During a survey of the sage grouse in Utah, it was noted that ground squirrels were preying on these birds, in one instance leaving only 3 or 4 chicks from a covey of 14 [7] The nests of California Valley quail are often victimized by the ground squirrels Indeed, when these squirrels, which were abundant, were materially reduced, quail became increasingly abundant and now are as plentiful as in early days Wherever the ground squirrels were removed from quail habitat, these birds increased We might expect from this that badgers, foxes, and coyotes, which prey upon these ground squirrels, would have a salutary effect on the quail

Those who would destroy predators at every opportunity should heed the remarks of Anderson,[8] who writes

and mountain goats that these animals had by 1920 become a serious nuisance and even a threat to human life After hundreds of bighorn had been trapped and shipped to restock depleted areas in the United States and Canada, the menace of overpopulation continued The sheep actually stood on roadside embankments and, as motorists drew level with them, attempted to leap over the cars These leaps often fell short, with attendant damage to people and cars Rocky Mountain goats became so numerous that they encroached and took possession of the upper bighorn ranges, driving the sheep to lower valley levels Deer ran amuck in the city of Banff, destroying gardens and lawns and creating a general disturbance In an effort to reduce this excess dangerous population of deer and other big game animals, wardens were instructed to cease killing predatory mammals Little change was noted for 3 years, then a perceptible decrease was observed in large game With an increase in their population due to protection, mountain lions once more became numerous and upon occasion actually entered the city of Banff, where they killed deer and sheep By 1930 the cougars had so routed the game herds that Banffites were alarmed and predatory animal control again came into force With the killing of a number of cougars, the herds have reinvaded the city and undoubtedly will again become a problem if predator control is carried to extremes

PREDATOR VALUES

Destruction of Pests Detailed studies on the food habits of predatory mammals have been conducted the world over, and it is now generally recognized that these animals perform a useful service in reducing rodents insects, and other pests of agriculture Naturalists generally believe that considerable reliance can be placed on predatory species, such as skunks foxes, weasels, badgers, and coyotes, in preventing destruction by injurious rodents Studies have long indicated that these species feed upon mice, ground squirrels, gophers, rabbits

and other species which often are responsible for much damage to crops

Undoubtedly predators exert a certain repressive influence on such forms, but it is hardly necessary to add that reliance should not be placed on this agency alone as a means of protection against rodents As an example, field mice, capable of producing a dozen litters in a year, breed so fast and often over such extensive areas that the slow breeding predators can scarcely hope effectively to control their numbers to a point where the destructive rodent will no longer be a menace If predatory species are feeding chiefly upon these small mammal pests or injurious insects to a large degree it is an implication that those species are occurring in such numbers that human agencies must be called upon to reduce them On the other hand, it is well to remind the reader that *all natural agencies*, including disease, adverse climatic conditions, and vertebrate enemies are necessary to prevent certain groups of animals from reaching their ultimate potential productivity If one such agency be removed, it may allow a pest to reach unprecedented populations in short order The value of predatory mammals has been abundantly demonstrated in this matter Alert predators do much to keep these rodents in check Instances of mouse plagues have been traced to the eradication of their natural enemies, thus permitting a rapid increase in the rodent population Howell states[9] that a number of years ago the foxes were purposely exterminated in Bohemia Following this action there occurred such a severe epidemic among the hares that it was necessary to reintroduce the foxes

The writer does not wish to convey the impression that predatory animals are entirely blameless The pursuit of certain livestock ventures, notably sheep raising in the wilder parts of North America, has often proven fruitless where coyotes are abundant Western Canada, which offers unusual opportunity for sheep raising supports only a fraction of the animals it is now capable of doing This

results largely from the abuodance of coyotes It has been established that few coyotes regularly hunt sheep, and those that do are unusually wary Only by the protection afforded by expert trappers can such a menace be eliminated

As Game Animals While most huoters are bird minded there is an ever increasiog army who follow the hounds in quest of certain predators Wherever the red fox occurs, hunters will be found who spend long days afield listening to the brassy notes of hounds ringing like bells oo the frosty air Even if the elusive one is oot bagged, the hunter usually feels well repaid by a sight of Reynard

As autumn approaches, the great Southern clubs organize their annual fox hunts Masters of the hunt must look to Northern trappers for their quarry New York foxes, trapped or dug from their dens as cubs, are shipped to Maryland, Virginia, and the Carolinas for these hunts Still huoting the fox finds much favor in New England

Coursing for coyotes is becoming more popular yearly in our Western states Trained wolfhounds and greyhounds, which can usually outdistaoce and overtake a coyote after a long spirited chase, are used exclusively The hunters follow on horseback, a dangerous procedure in some of the rougher sections, or follow the less hazardous practice of using a car When the dogs finally bring the coyote to bay, it is shot or clubbed by one of the hunters Good dogs are instrumental in capturing many coyotes in a single season

Wildcats are regularly hunted with dogs, and the spitting quarry, treed after a chase, is usually considered high-class game by both Eastern and Western sportsmen The pelt of a mountain lion, prepared into a rug or wall piece, is a trophy many hunters treasure They are hunted with dogs wherever they occur in sufficient numbers in the Western states Several other predators are eagerly pursued by a large fraternity of hunters who find in them an unrivaled sport

Fur Values We have seen in Chap XVII that the magnitude of the fur industry and its reliance upon wild-caught

American fur bearers can scarcely be realized by the uninitiated Young men and old everywhere supplement their income by harvesting the fur crop In 1928 it was said that the fur catch in the United States was worth $60,000,000 to the trapper Among the more important species contributing to this rich harvest are certain predatory mammals, as the fox, skunk, opossum, weasel, mink, coyote, and several others Even in thickly settled districts these animals may still be found in some numbers Coyotes still invade the city limits of Denver, and fox tracks may yet be seen in the new-fallen snow a few miles from New York

The members of many state conservation departments are alive to the value of these furred predators and provide suitable protection for the various species while their fur is unprime Other states, perhaps influenced by political pressure rather than by biological considerations, give little heed to the alarming status of these important species and give some of them little or no protection Indeed, not a few misguided individuals have placed a price on the heads of such vermin and as a consequence have squandered funds which might better have gone toward restoration and improvement of game cover

Reduction of Diseased Animals Olson[10] believes that the timber wolf in northern Minnesota, instead of being a hazard, is a distinct asset to big game types After long investigation, he indicates that the great majority of the killings are of old, diseased, or crippled animals Such purely salvage killings are assuredly not detrimental to either deer or moose, for without the constant elimination of the unfit the breeding stock would suffer The wolf appears to be a natural stimulus to a herd s alertness and injects the primitive element of danger without which most big game animals lose much of their natural charm It would seem from this that large wilderness areas can support both herbivores and carnivores without danger to the herds of wild deer

In Ontario, timber wolves and coyotes, in spite of a bounty in which 33,000 animals were destroyed at a cost to the Province of half a million dollars, do not appear to have been reduced materially. On the contrary, there is much evidence that wolves are increasing and the population appears to be

FIG. 91.—The end of the chase. Predation is not always what it seems. These timber wolves will kill the exhausted white-tail doe, but by doing so they have made room for more. In Ontario the wolves and coyotes, in spite of a bounty, have steadily increased. At the same time, deer have shown a notable population increase in the same territory and are actually extending their range.

much greater now than 10 years ago, the effect having been to kill off the surplus and make things easier for the survivors. In spite of this increase deer likewise have shown a remarkable increase not only in numbers but in the extension of their range in Ontario at the same time the wolves were increasing. This surely seems ample argument that predator control, at least in this instance, is quite useless. Moreover, it suggests

that wolves or some other sizable predator is a necessity in Ontario (Fig 91) The bobcat kills many deer in Northeastern United States, destroying fawns and adults weakened during the severe northern winter A bounty has not appreciably lessened the bobcat population of Vermont but, in spite of their continued abundance, deer are on the increase

It is most difficult to determine whether predatory mammals exercise any selection in their prey or whether the health and virility of the prey species determine which individuals will be destroyed In a study of the lion in the mountain country of New Mexico and Arizona, Hibben[11] recovered 11 deer which had been killed by these cats *In every instance* the remains of the kill indicated abnormal or subnormal characteristics, a fact which is almost too complete to be mere coincidence Many have claimed that the lion kills at will and takes the best as he chooses The evidence obtained by Hibben does not support this theory The trail of one lion indicated he had made three unsuccessful attempts to strike down a deer before he was successful, and he was finally successful only against a buck which had a large abscess in the region of the larynx, completely filled with botfly larvae This condition had rendered breathing difficult and resulted directly in its capture by the puma (Fig 92)

Those who indulge in futile predatory mammal persecution in areas where the predator has been little studied and where as a consequence, scarcely anything is known regarding its relation to legitimate prey, might well consider the remarks of Errington,[12] who, after extensive field observations, states

FIG. 92.—Mountain lion stalks a mule deer. Mountain lions feed largely upon deer, but a recent study suggests that the deer killed by the lions are in some manner unfit. Predatory mammals, if they do not exercise as a culling agent, often keep herbivorous species within desirable limits.

tions that must disappear anyway, is incidental It should not be regarded as a threat to the permanent nucleus, which, barring drastic change in environment, will continue to occupy all livable quarters and produce the usual annual surplus The surplus is strictly temporary, and generation after generation is frittered away Whether taken by predators or otherwise lost the surplus must disappear, population sooner or later coincides with carrying capacity

Limited predator control is justified only under abnormal circumstances, for example, where a marauding mink has taken up its residence about the environs of a fish hatchery or when skunks become unusually numerous on a game farm The true significance of predation as a natural phenomenon has met with all too meager study Until predator prey relationships are better understood by the layman, many of our most desirable mammals will continue to be persecuted, until eventually they must go Widespread condemnation of our valuable predatory mammals, based on mere allegations and false premises, is deplorable We can no longer overlook their true significance and the important role they play in nature